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SEWAGE STABILIZATION PONDS IN WISCONSIN: A REPORT ON BIOLOGICAL AND CHEMICAL INVESTIGATIONS, APRIL 1957 - AUGUST 1958

Kenneth M. Mackenthun, et al

Wisconsin Committee on Water Pollution
Madison, Wisconsin

January 1959

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SEWAGE STABILIZATION PONDS IN WISCONSIN

A Report on Biological and Chemical Investigations
April 1957 - August 1958

1. Sewage Treatment - waste stabilizat. Pond
2. Wisconsin

by

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PUBLIC HEALTH BIOLOGISTS

COMMITTEE ON WATER POLLUTION
Madison, Wisconsin

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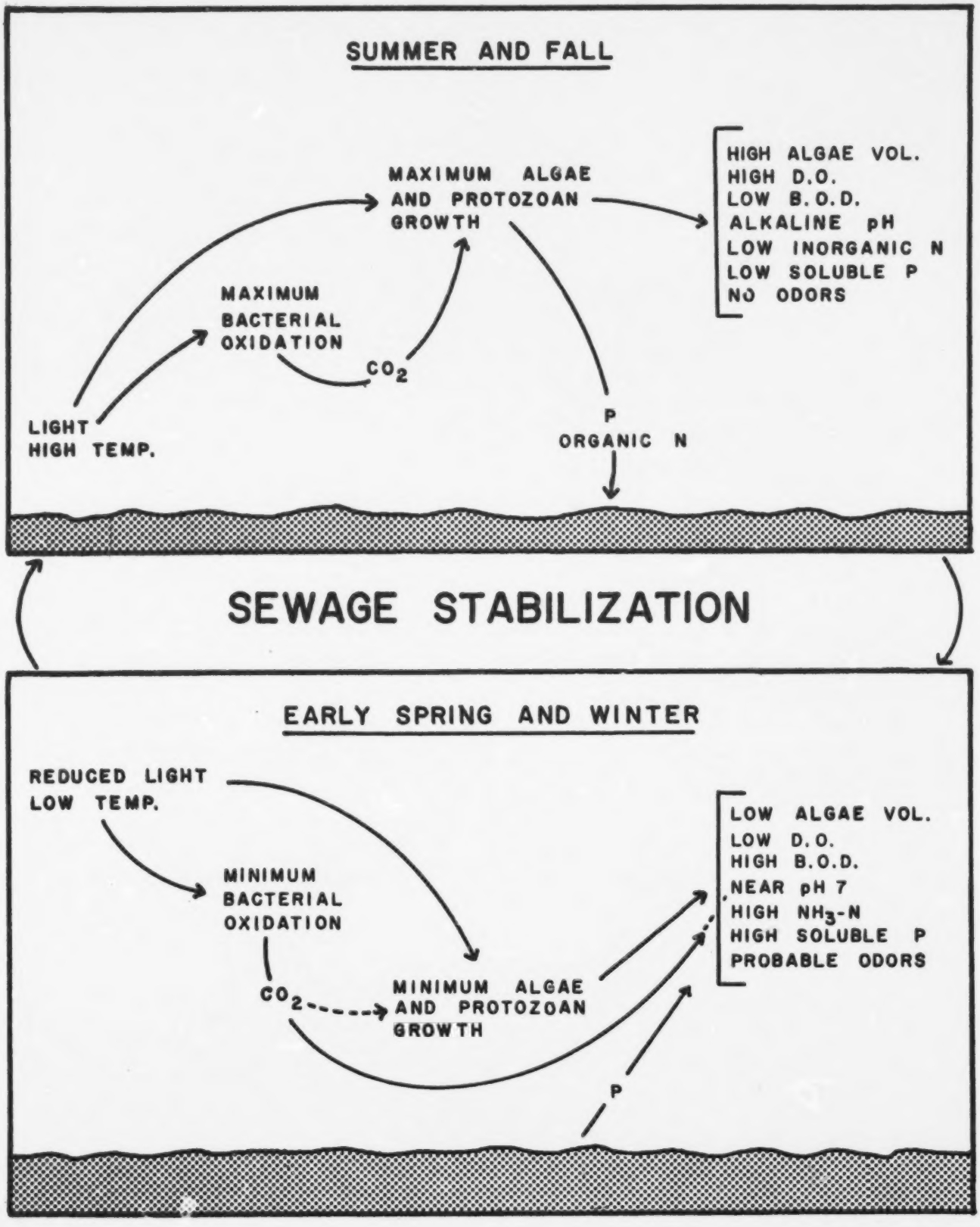

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INTRODUCTION

Sewage stabilization ponds for the treatment of raw or partially pre-treated sewage have become very popular among the smaller municipalities. This has been especially true in the northern plains states, in the southwest, and more recently in the midwest. The ponds provide a degree of treatment comparable to that of a complete treatment unit. Basically, the stabilization process consists largely of the interaction of bacteria, algae, and other associated organisms in the biological community. In the process, relatively unstable organic matter is converted principally to a more stable algal mass, plus some inorganic nutrients.

During 1955, Wisconsin became interested in sewage stabilization ponds, and, following the approval of plans by the State Board of Health, four such units were constructed and placed in service during the latter part of 1956.

Table 1

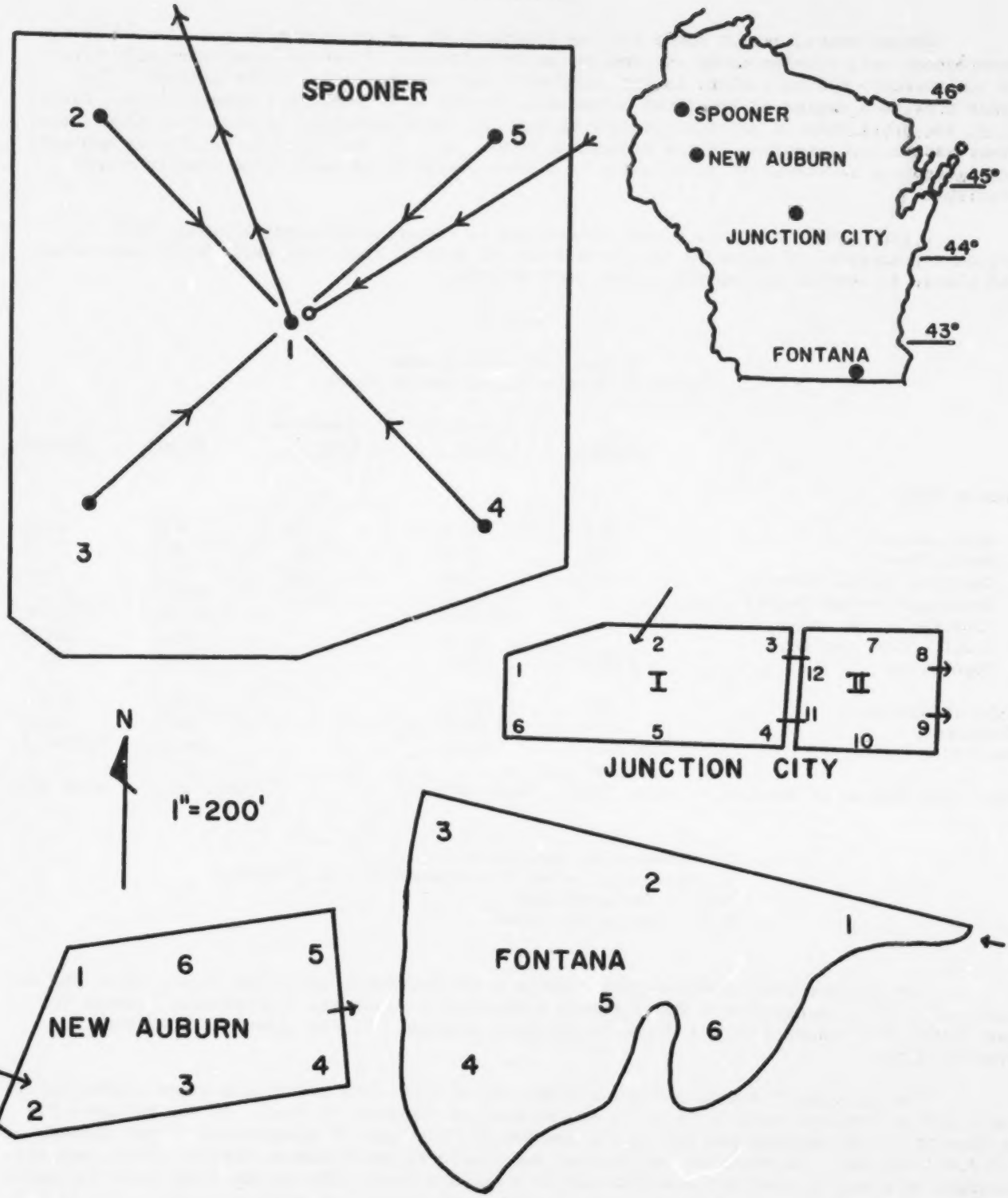
Design and Loading Data
Wisconsin Sewage Stabilization Ponds

	Fontana	Junction City I	Junction City II	New Auburn	Spooner
Design Data					
Area (acres)	7.0	1.75	.83	2.7	22.0
Depth (feet)	4.0	3.5	3.5	5.0	5.0
Capacity (mill. gals.)	9.0	2.0	.95	4.5	36.0
Detention period (days)		55.0	26.0	160.0	125.0
Flow (gals. per day)		36,000		28,000	288,000
B.O.D. (lbs. per day)		60.0		75.0	725.0
Population	2,800[1]	360.0		450.0	3,000.[2]
1950 Population	726	330.0		371.0	2,597
Treatment	T.F.	None		Sed.	Sed.
Receiving Water	Sub-soil seepage	Marsh		Marsh	Yellow R.
Date Pond Placed in Service	Aug. 1956	Oct. 1956		Oct. 1956	June 1956

1 Summer-time population
2 Plus milk wastes from Spooner Co-op. Creamery
Sed. - Sedimentation
T.F. - Trickling Filter

The Fontana stabilization pond follows a pre-treatment trickling filter unit, has an area of 7 acres, a depth of 4 feet, serves a seasonally fluctuating population between 700 and 2,800, and disposes of its waste by sub-soil seepage. It was placed in operation in August, 1956.

The village of Junction City, a community of 330, constructed a 2-stage stabilization unit with a combined area of 2½ acres and an average depth of 3½ feet. It was designed for a flow of 36,000 gallons per day, and a loading of 60 pounds of biochemical oxygen demand (B.O.D.) per day. It receives raw sewage, was placed in operation in October, 1956, and discharges to a marshy area and subsequently to a small stream. The sewage flows into the upper end of the larger pond, passing into the second pond through two submerged pipes, and is discharged from the second pond also by means of two pipes (Fig. 1).



WISCONSIN SEWAGE STABILIZATION PONDS 1957
Fig. 1

The village of New Auburn, located in the northwest section of the state, constructed a stabilization pond of 2.7 acres in a marshy type of terrain. The pond has a depth averaging 5 feet, is designed for a flow of 28,000 gallons per day with a loading of 75 pounds of B.O.D. per day, and has a designed detention period of 160 days. The pond receives settled sewage and discharges into the adjoining marsh.

The Spooner stabilization pond is the largest thus far constructed in Wisconsin. It serves the city with a population of approximately 2,600, and a creamery. It is 22 acres in area, averages 5 feet deep, is designed for a flow of 288,000 gallons per day, with a loading of 725 pounds of B.O.D. The designed detention period is 125 days. The lagoon receives settled sewage and discharges into the Yellow River. The wastes from the Imhoff tank at Spooner are pumped from the wet well to the stabilization pond. Sewage enters the pond through a centrally located orifice and discharges through a collection system placed 18 inches off the bottom at the four corners of the pond, with elevation controlled by a common variable overflow weir. The collected pond effluent is again brought to the center of the pond and is discharged through a common pipe.

Figure 1 shows the layout of the four stabilization units, the comparative size, and the sampling stations followed throughout the survey as denoted by the numbers appearing in the figure. One of the prime purposes of the study was to determine the feasibility of pond stabilization of sewage for the climate of Wisconsin. In these four waste treatment units, we have an excellent opportunity to study this problem through about $3\frac{1}{2}$ degrees of latitude, going from Fontana in the extreme southern part of the state to Spooner which lies about 350 miles to the northwest.

The climate of Wisconsin is influenced by the general storms which move eastward along the northern border of the United States, and by those which move northeastward from the southwestern states to the Great Lakes. In the colder part of the state, minimum winter temperatures are extremely low practically every year. In 36 of the last 50 years, a minimum of -40°F. or lower has been recorded in some parts of the state. Markedly cool periods also may be experienced in summer.

Table 11A (Appendix) summarizes the climatological data in the four general areas from the northwest to the southeast portion of the state for the period in which the pond stabilization studies were conducted. In general, the weather was cloudy, cold, and wet in the northern section and quite dry in the central and southern areas of the state. The percent possible sunshine has a bearing upon efficient algae production. Generally speaking, this was below normal for the entire period of study with the exception of February and May in 1958 when the per cent possible sunshine was some 20% above the long-term mean.

With the exception of the winter period, December 1957, January 1958, and the early spring of 1958, the temperatures averaged below the long-term mean for the entire period of study. The annual average temperature for the area around Spooner in the northwest sector of the state is about 42°F. whereas, the average annual temperature in the Fontana area is about 48°F. The normal precipitation for the northwest section of the state averages slightly over 28 inches per year compared to about 33 inches per year in the southeast section. The area around Spooner and New Auburn received slightly more rainfall than normal during the period of study, whereas the central and southern areas of the state were quite dry and averaged below normal in nearly every month, and several inches below normal for the period of study. Snow covered the ground from mid-November to mid-March in the central and northern part of the state.

The study of sewage oxidation ponds was begun in May 1957, and continued monthly through August 1958. Samples were collected at the stations indicated in Figure 1, and composited for complete chemical and biological analyses at least once each month during this period. In addition, 24-hour surveys of the treatment unit were conducted to determine the efficiency of the unit during both winter and summer conditions. Since the stabilization pond at Spooner was especially adaptable to a study of bottom-dwelling invertebrates, this particular phase of the study was undertaken in the fall of 1957 and again in the spring

and fall of 1958. A tabulation of these various data appear in the 21 tables in the appendix. Tables 1A through 5A list the chemical data; 6A through 10A, the 24-hour survey data; 11A, the climatological data; 12A through 17A, the plankton data; 18A, the invertebrate studies; 19A, sediment accumulation; and 20A and 21A, light transmission and penetration.

METHODS OF STUDY

Chemical Analyses

During this study, water samples for chemical analyses were taken at the sewage treatment installations at approximately 4-week intervals. In the initial phase of the study, permanent sampling stations were positioned at three points in the treatment unit. The pond influent was sampled as near as possible to its point of entry into the pond. The stabilization ponds were sampled at the stations indicated in Figure 1, and a sample of the pond effluent was collected whenever possible. All pond chemistry samples represent surface water conditions since they were taken from the upper strata at least six inches below the surface. At Fontana, Junction City, and New Auburn, these samples were taken approximately 10 feet offshore. At Spooner, the samples were taken out in the pond by boat during the open water season. The Junction City and Spooner ponds were discharging so that it was possible to obtain an effluent sample at the outfall. At Fontana and New Auburn, no outflow was available, consequently for these latter ponds, the effluent was considered to be equivalent to the average of pond samples taken more than 50 feet from the inlet.

Samples for 5-day B.O.D. determinations were collected each month from the pond influent and effluent. A sample for water chemistry was obtained from the pond itself by compositing 400 cc. of sample from each of the sampling stations. Total organic nitrogen, free ammonia nitrogen, nitrites, nitrates, soluble phosphorus, and total and suspended solids determinations were made on these samples. All chemical analyses followed the procedures outlined by Standard Methods for the Examination of Water, Sewage and Industrial Wastes, 10th Edition, 1955.

Dissolved oxygen samples were taken at selected sampling stations from the upper one foot of water with conventional equipment. During the periods of ice cover, these samples were taken approximately 6 inches below the ice. The Alsterberg (azide) modification of the Winkler method for dissolved oxygen determination was used throughout the study.

The temperature and pH of the surface water of each pond was recorded at a number of the permanent sampling stations so that a pond mean could be expressed. In addition, two other types of studies were made on the facilities to obtain an estimate of the performance of the ponds in stabilizing the sewage loading they received. These were, (1) collecting samples for chemical analyses of the influent and effluent, where present, on a proportionate flow basis at regular intervals for a 24-hour period, and, (2) studies of the changes in the dissolved oxygen concentration at different depths in some of the ponds from dawn to dusk at different seasons of the year. Determinations of total organic nitrogen, free ammonia nitrogen, nitrites, nitrates, total and soluble phosphorus, total and suspended solids, and 5-day B.O.D. were made on 24-hour composites. Studies were made of the magnitude of dissolved oxygen changes that occur during the day at different depths in the ponds receiving raw and settled sewage. Late winter, spring, and summer conditions were observed at Junction City (Pond 1), New Auburn, and Spooner.

These samples were obtained by dropping the open end of a weighted $\frac{1}{4}$" polyethylene tube to the desired depth and slowly drawing water up through the tubing by means of a series of vacuum bottles. A small basket-ball pump with reversed elements was attached by tubing through a rubber stopper to a calibrated 500 cc. glass jar. This jar was coupled in series through a second stopper to a 60 ml. dissolved oxygen bottle. The proximal end of the weighted polyethylene tubing led to the bottom of the D.O. bottle. A sufficient vacuum was created in the calibrated jar to allow such a quantity of pond water to flow through the

system so as to fill the D.O. bottle four times. The stopper of the D.O. bottle was then removed and the contents were used for a determination. Samples, which proved to be representative of a given stratum, were thus taken from specific depths in the water column at several stations within the pond. This sampling was done well out in the pond; through the ice in the winter, and from a boat in the summer. A pond mean for each depth was calculated from the individual results.

Biological Analyses

Three types of biological collections and determinations were made for this study: (1) phytoplankton, (2) benthic fauna, and (3) coliform density.

An estimate of the phytoplankton standing crop in each of the ponds was made at monthly intervals using a 200 cc. sub-sample of the chemistry sample composite. A sufficient quantity of commercial formaldehyde was added to each of these sub-samples to preserve the organisms in approximately a 4% formalin solution. An aliquot was then withdrawn and the suspended material that it contained was concentrated on a 1" diameter type HA Millipore membrane filter. The aliquot varied in amount from 1.0 ml. to 25.0 ml. depending upon the density of the particulate matter in the sample. A drop or two of microscope immersion oil was then placed over the residue and the filter was stored in the dark to dry. As the oil replaces the water in the interstices of the filter, it becomes transparent. In this condition the filter was placed upon a glass slide and cover slipped.

The number of organisms per milliliter of original sample was determined in the following manner. Using a Whipple eye-piece, and a low-power (150X) magnification, an enumeration field was delimited so that as the filter was scanned, the most common of the large phytoplankton organisms would occur within it approximately 90% of the time. Using this field size and magnification, the presence or absence of large alga forms in 30 fields was recorded. A field size was similarly selected at a higher magnification (645X or oil immersion) for the enumeration of minute forms. Presence or absence in 30 of these fields was recorded for those species falling into the latter category.

It has been demonstrated that the phytoplankton becomes distributed at random over the surface of the filter as the water of the aliquot is drawn through it by suction. Therefore, it is not necessary to count the number of organisms in each field, but only to know the percentage of fields in which each species occurs. Knowing this, the number of individuals of each species per field size used is then determined by referring to a table compiled by Fracker and Brischle. With this information and a properly calibrated microscope, the following formula may be used to obtain an estimate of the number of individuals of each species per milliliter of the original water sample:

Ind. per ml. = (individuals per field)(microscopic fields on filter)/ milliliters filtered.

The number of milliliters filtered was that amount of sample which could be brought down without crowding the organisms, making them indistinguishable for scoring. It has been demonstrated that with this method of concentrating and scoring, the actual value for the average number of organisms per field which one would obtain by counting them, and the theoretical value taken from the table are often identical, or, if different, are not significantly so in a statistical sense.

The number of individuals of each species that was encountered in a sample was totaled. This total, however, could not be used as a strict criterion for comparing the production of algae from month to month or between ponds, since it was found that small forms were exceedingly numerous in certain samples and yet their total bulk was relatively small. Conversely, small numbers of large organisms were found to constitute a relatively large portion of the total volume. Therefore, an estimate of the algae volume, species by species, was made for each of the enumerated samples. The average dimensions of the very numerous species were estimated by measuring 40 individuals. For the less common forms, 20 individuals were measured. This resulted in measuring 40 individuals of species that contributed more than 5 p.p.m. to the total volume of phytoplankton in the sample, and 20 individuals of those

species contributing less than 5 p.p.m. to the total. A complete set of measurements were made for the organisms enumerated in each pond. When it was observed that species size was significantly different between two samples, a second set of measurements was made. Knowing the number of individuals of a species per milliliter of sample and the average volume of the organism, the volume contributed by each species was expressed in parts per million by using the following formula:

$$\text{Volume (p.p.m.)} = (\text{organisms per ml.})(\text{ave. species volume in cubic microns})\ 10^{-6}$$

The total volume of phytoplankton in a sample was the sum of each species contribution.

In addition to the quantitative information thus obtained, a qualitative study was made of each of the monthly samples.

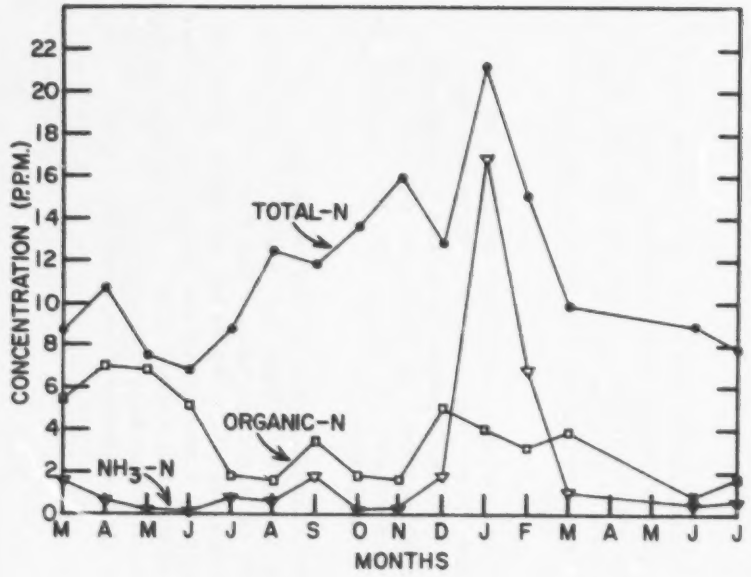
Samples for the enumeration of bottom fauna were collected with an Eckman dredge. The collected sample was washed in water, strained through a U.S. Standard No. 35 sieve, and preserved for laboratory identification and enumeration. The samples collected during the early spring (1958) were found to contain both living and dead material in good condition, thus these samples were not preserved but were warmed in the laboratory and the organisms sorted from the debris in the fresh state. The results of the enumerations were expressed as the number of organisms per 36 square inches of pond bottom.

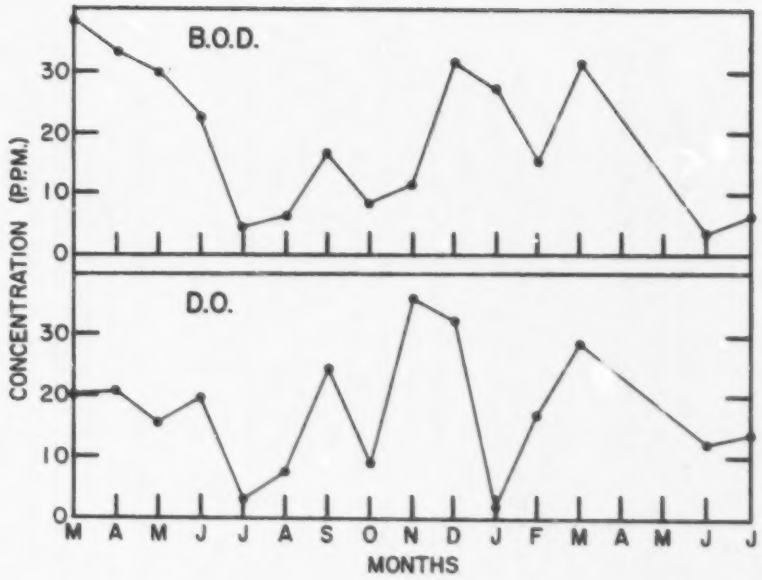
Bacteriological determinations of the most probable number (MPN) of coliform organisms were made on samples collected monthly at various points in each of the sewage treatment systems. The sewage was chlorinated only at New Auburn. This was done periodically to combat odor at the treatment plant. The influent, the ponds at selected permanent stations more than 50 feet from the inlet, and the effluent where an overflow existed were sampled. The several pond samples were of surface water and were used to express a pond mean. If a pond was not discharging, the effluent MPN was considered to be equivalent to the average of pond samples taken more than 50 feet from the inlet. MPN values are expressed as the number of coliform organisms per 100 ml. of sample.

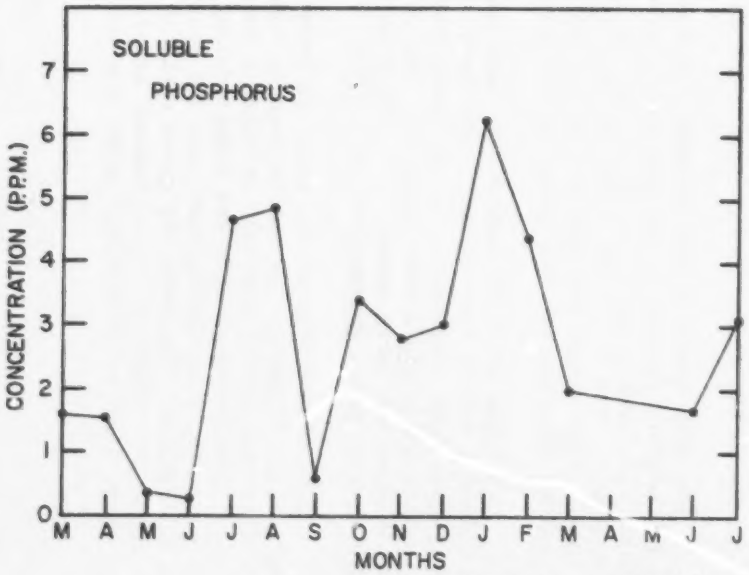
Physical Studies

The depth to which a sufficient quantity of incident light penetrates to maintain photosynthetic oxygen production is important to the structural design of sewage stabilization ponds. A Whitney light meter built at the University of Wisconsin was used in this study to ascertain light relationships. Its photronic cell is sensitive to wavelengths in the visible light range. The depth at which various percentages of the incident light remained was measured under ice cover and again at several times during the open-water season in the ponds receiving raw and settled sewage. The measurements were taken at a number of stations well out in the ponds, and these results were used to obtain a pond mean.

Sediment accumulation on pond bottoms was measured in October of 1958. This was approximately two years after the ponds were put into service. A sediment and soil core was obtained by forcing a piece of 3/4" glass tubing into the bottom. The soil of the pond bottom became sufficiently compacted to serve as a plug in the end of the tube while the sample was being brought to the surface. It was found that two layers of settled material could be characterized in the cores. These were, (1) an upper layer of macroscopic solid particles with a non-homogeneous appearance being variously colored by algae and decomposing bits of matter, and, (2) a lower layer blending into the soil and composed of finely divided organic material having a homogeneous black appearance. The depth of these layers was measured. Samples were taken by boat at equally spaced stations along lines radiating from the inlet. Data were obtained for the pond at Fontana, Junction City, and Spooner where the bottoms were a clay or sandy loam. The pond bottom at New Auburn was principally a peat, and sediments could not be discerned from the original parent material.







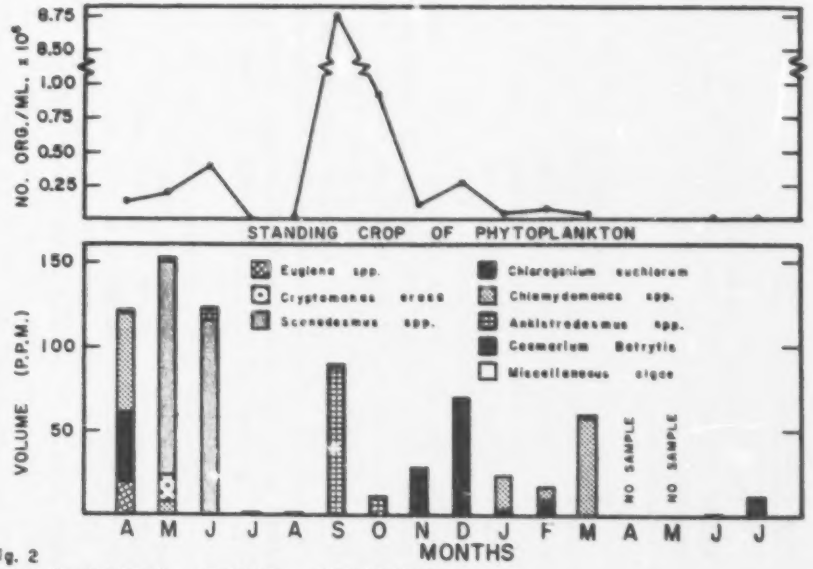


Fig. 2

FONTANA SEWAGE STABILIZATION POND STUDIES

MARCH 1957 - JULY 1958

RESULTS OF STUDY

Fontana Stabilization Pond

The Fontana sewage stabilization pond of 7 acres receives sewage effluent from a trickling filter treatment system. Studies were begun on this pond on March 26, 1957, and discontinued on July 22, 1958. With the exception of April and May, 1958, monthly samples were collected.

Table 1A presents a summary of the chemical tests taken and Figure 2 shows the graphic trends for some of the more important tests as well as the biological data. From these data, total nitrogen is found to reach a low point in the curve during the summer period of June and July of between 7 and 8 parts per million (p.p.m.) It increases in the fall of the year, attaining a peak of 21 p.p.m. during the month of January. The organic nitrogen fluctuated between 1 and 7 p.p.m. throughout the course of the study and averaged 3.5 p.p.m. for the course of the study. Ammonia nitrogen remained very low in this particular pond except during the months of January and February at which time it composed the major portion of the total nitrogen found. Nitrite nitrogen was low at all sampling times. Nitrate nitrogen averaged 5.4 p.p.m. for the entire period of study. Following June, 1957, and with the exception of January and February of 1958, the nitrate nitrogen formed the bulk of the total nitrogen found in the stabilization pond. Soluble phosphorus was quite low compared with the other stabilization ponds, averaging only 2.7 p.p.m. for the period of study. The peak of 6.2 p.p.m. was reached during the latter part of January.

There was considerable fluctuation in the B.O.D. between the different sampling dates. There is, however, a general tendency for the B.O.D. to be somewhat higher during the winter months. The B.O.D. averaged 19.1 p.p.m. for the samples taken throughout the study, whereas grab samples of the stabilization pond influent taken at the same time averaged 17.6 p.p.m. The dissolved oxygen was supersaturated during most of the study of the Fontana pond. It reached its lowest point of 2.0 p.p.m. during the end of January. It was at this time also that odors were detected from the water beneath the ice. Some thin ice was present as early as the first part of December. The ice cover became about 10" thick during the latter part of January, and this condition persisted until the early part of March. The pH fluctuated between 7.6 and 10.2 throughout the course of the study, reaching a low point in the cycle during January and February.

For some unaccountable reason, the Fontana stabilization pond had the lowest reduction in coliform density on two different occasions of any of the stabilization ponds studied. In January and June, the reduction in coliform organisms dropped to 64% and 80% respectively. Otherwise the reduction in coliform density usually ran well over 99%. The MPN in the pond ranged between 200 and 19,000 with the exception of the months mentioned. The highest MPN recorded was 1,760,000 on January 30, 1957.

Two types of plant communities made use of the inorganic nutrients supplied by the pond influent during the course of the study. For the first year, phytoplankton was the primary producing component. In the early summer of 1958, a filamentous algae Cladophora fracta var. lacustris became dominant. The phytoplankton growth at this time was poor, the water between the large masses of filamentous algae was relatively clear, and the rooted submerged aquatic weed, Potamogeton pectinatus, became established.

The productivity of the pond, in terms of the standing crop of phytoplankton, is summarized in Figure 2. It can be seen by comparing the graphs that the number of organisms per milliliter is only remotely related to the volume of algae present. The rich green growth of the spring of 1957 was absent during July and August. The water on these sampling dates was alive with Cladocerans, and the resting eggs of these organisms made small windrows along the shores. The pond was green again in September with a good growth of Ankistrodesmus. This bloom diminished with cold weather and flagellated organisms, Chlorogonium and Chlamydomonas, were found to be dominant under the ice cover that extended from November through the

February sampling date. Chlamydomonas enjoyed a growth spurt shortly after the ice melted. In the summer of 1958, the character of the pond flora shifted to the filamentous algae submerged phanerogam community. In general, Scenedesmus and Ankistrodesmus predominated in the warm months, and Chlamydomonas and Chlorogonium when the water was cold. Table 12A shows the phytoplankton to be composed principally of species belonging to the green algae group. When a heavy growth was achieved, one or two species made up all but a very small fraction of the total volume of algae.

A number of interactions between the pond flora and certain aspects of the water chemistry are evident from these data. Nitrogen and phosphorus, together with carbon and hydrogen, are recognized as the most important constituents of the protoplasm of plant cells and for that reason are inorganic nutrients of prime importance to growth.

Nitrogen enters the pond principally as free ammonia (Table 6A). This is the chief decomposition product of the proteins in the raw waste. In the presence of excess oxygen produced by the algae, nitrification occurs in the pond and the ammonia is oxidized to nitrite and then to nitrate. Ammonia nitrogen was found to accumulate in the pond only during the late winter when photosynthetic oxygen production was curtailed by heavy snow cover over the ice. This concentration of ammonia nitrogen was contributed by the influent and by reactions at work within the pond, principally at the bottom.

Nitrates are assimilated by algae, hence at the peaks of alga growth, they would be expected to be low and vice versa. This was found to be generally the case (Table 1A) with an initial build-up of nitrates commencing in July and August of 1957. This reserve was tapped by the population growths of September and December. In January and February of 1958, the inorganic nitrogen occurred principally as ammonia, and low nitrate and algae volume occurred together. In March, the amount of ammonia nitrogen was decreased and the algae population had increased at the expense of the inorganic nitrogen reserve. It can be noted that even the most vigorous growths of algae did not completely consume the available inorganic nitrogen, indicating that this nutrient was not limiting to the growth of the phytoplankton population.

The organic nitrogen curve (Fig. 2) rises and falls similarly as the algae volume. This suggests that the chemical determination is primarily affected by the abundance of algae in the sample and only secondarily by the organic nitrogen in the influent and that arising from the bottom sediments. This is as would be expected in a relatively clean bottom pond receiving a treated influent.

The good correlation of the B.O.D. curve with the algae volume appears to be present for similar reasons. The B.O.D. of the influent is low (Tables 1A and 6A). Consequently, when a substantial B.O.D. occurred in the pond, the organisms growing there were responsible for a sizeable fraction of it. The pond B.O.D. was often found to exceed that of a grab sample of the influent.

Algae growth had a decided effect upon the soluble phosphorus content in the pond. Low points in the soluble phosphorus curve (Fig. 2) correspond to the peaks of algae production. The converse is also true. The maximum soluble phosphorus peak occurs in January when there was a substantial growth of algae in the pond. Low water temperatures and associated assimilation rates, together with the release of phosphorus from the bottom sediments under low dissolved oxygen conditions, are probably responsible.

The characteristics of the data that have been discussed are related to a new pond. The permanent pattern of flora development is in question since the phytoplankton of the summer of 1957 was replaced in 1958 by a filamentous algae-submerged aquatic weed community.

An estimate of the depth of bottom sediments in the pond was made in October, 1958 (Table 19A). This was two years after the pond was put into operation. The "A" or upper layer of sediment was a light greenish-brown color. Microscopically, it was composed of well-colored cells of Cosmarium Botrytis in very large numbers, small fragments of Cladophora

fracta in less amount, and small amounts of miscellaneous algae, soil particles, and bits of decomposed organic material. The "B" layer was deep black in color. This was due to the predominance of small fragments of organic material mixed sparingly with fine soil particles and empty frustules of diatoms. The lower layer of sediments graded into the clay loam of the pond bottom. The total mean depth of the sediment was 3.0 cm. All stations were more than 50 feet from the inlet. In general, the amount of sediment decreased as distance from the inlet increased.

A 24-hour survey was completed on the Fontana sewage treatment plant and stabilization pond on August 20, 1958 (Table 6A). Based upon the strength of the influent in this season of estimated peak loading, the percentage reduction in the stabilization pond for B.O.D. was 88.9%; total nitrogen, 77.4%; inorganic nitrogen, 80.6%; and soluble phosphorus, 82.4%. The Fontana stabilization pond received a very light loading of 5.0 pounds of B.O.D. per 100,000 square feet per day. Total nitrogen loading was 8.6 pounds, and total phosphorus was 4.9 pounds per 100,000 square feet per day.

Junction City Stabilization Pond

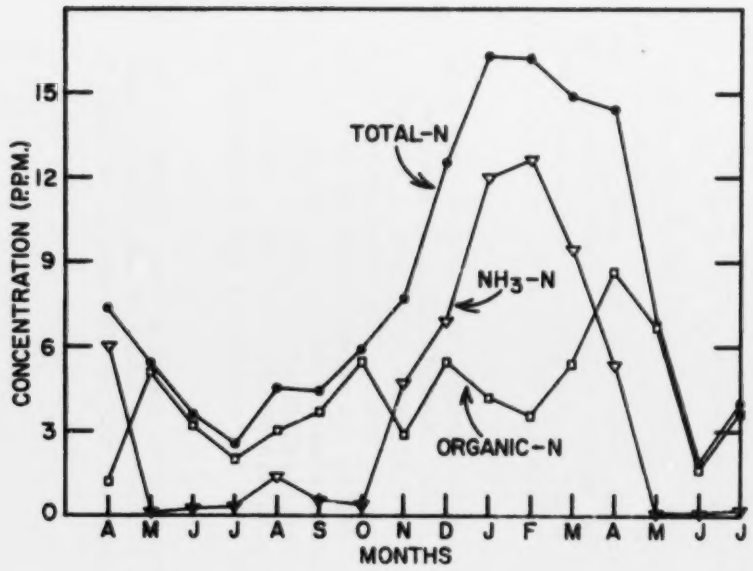
The raw sewage of Junction City receives two-stage stabilization treatment. The first pond is 1.75 acres in area and the second pond 0.83 acres in area. Studies on these ponds were begun on May 14, 1957 and continued monthly until August 26, 1958.

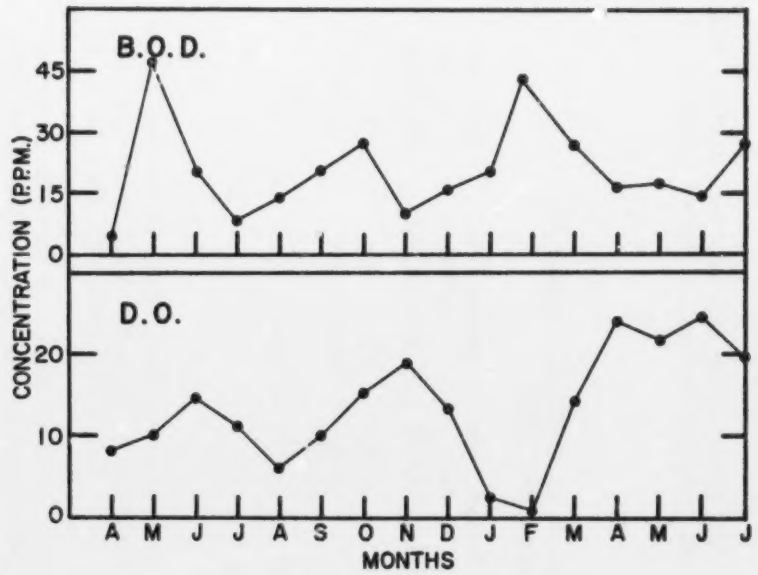
The chemistry of the first pond of the series (Table 2A and Fig. 3) appears typical for one receiving a light loading. The nitrogens are quite low during the summer months, begin rising in the fall, and reach a peak during January, February, and March. Following this, there is a decline during the late spring back to the summer low. The total nitrogen is composed principally of organic nitrogen with the exception of the winter months at which time the ammonia nitrogen forms about 75% of the total. Ammonia nitrogen averaged only 3.6 p.p.m. for the entire period of study, and during the winter months attained a peak of 12 p.p.m. in the pond. The soluble phosphorus content also is quite low in the summer months, rising slightly in the fall and attaining a peak of only 2.75 p.p.m. during the month of February. Following this, there is a sudden drop back to pre-winter conditions.

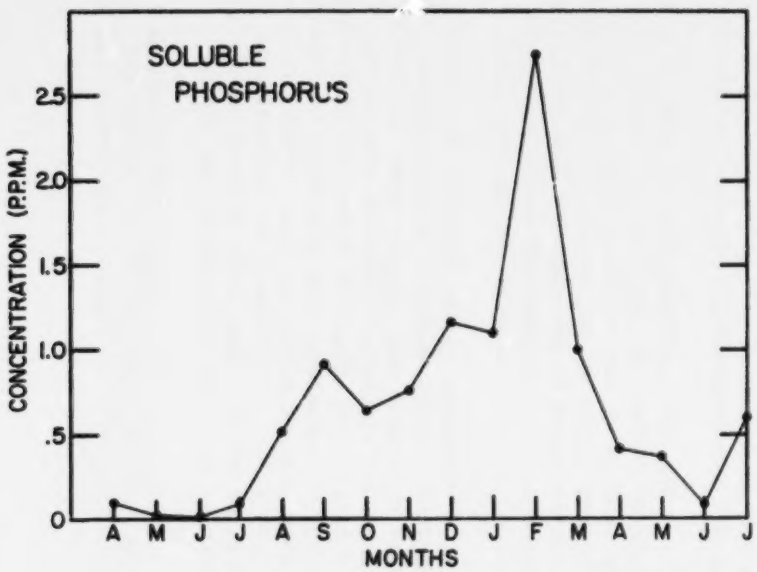
The B.O.D. displayed considerable fluctuation between about 10 and 40 p.p.m., and averaged 21.7 p.p.m. for the entire period of study for Pond No. 1. Grab samples of the influent B.O.D. averaged 153 p.p.m., and the effluent of Pond No. 2 averaged 9.3 p.p.m., showing a percentage reduction of 93% for the entire study. The lowest reduction through the two stabilization ponds was the 79% recorded in March. The dissolved oxygen concentration remained good throughout the study with the exception of February when it was reduced to a trace in Pond No. 1. The pH ranged near 10 during the spring and summer, gradually decreasing in the fall to a low of 7 in the latter part of February. Ice formed on the ponds in late November and remained until early April attaining a thickness of 15 inches. Odors were perceptible from the water in January, February, and March. No odors were detected during open-water periods.

Oxygen production at different depths in the first pond was studied in August, 1958, using a light-dark bottle technique. A two-liter pond sample was composited from three depths at each of four stations. Sub-samples of this were siphoned into 60 ml. D.O. bottles. A set of three plain bottles and three wrapped in aluminum foil was suspended in the pond at each of four depths for a 2-hour period (Table 2). The initial D.O. concentration in the bottles was determined from three samples drawn from the composite. At the end of the suspension period, D.O. determinations were made on all bottles. The difference between the initial D.O. concentration and that at the end of the experiment is recorded in Table 2 in parts per million.

Light is the principal factor influencing the production of oxygen at each level in this experiment. As the light intensity in the pond decreased, the oxygen production also decreased. The compensation point, or the level at which the photosynthetic oxygen production rate is equivalent to the total respiratory use, lies near 30 inches. The respiratory







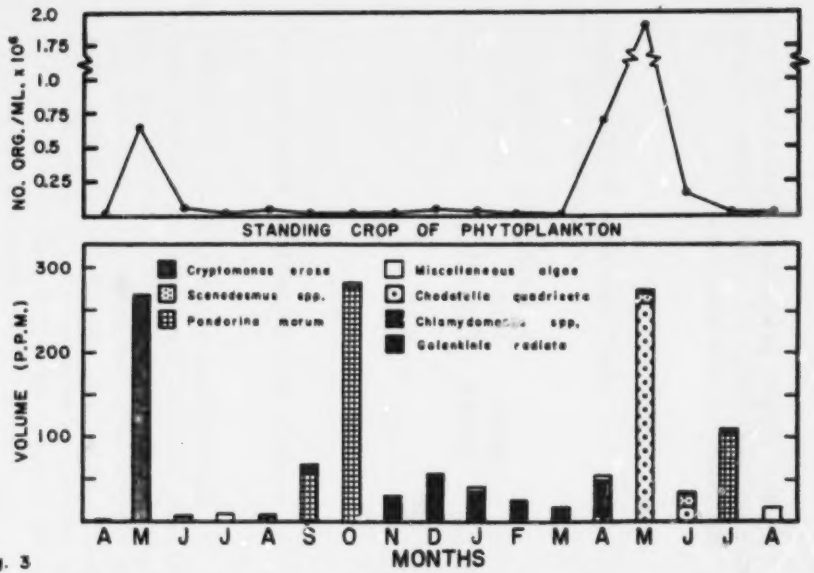


Fig. 3

JUNCTION CITY SEWAGE STABILIZATION POND STUDIES

POND I APRIL 1957 - AUG. 1958

use of oxygen was essentially the same from top to bottom. Respiratory use below 30 inches exceeded the oxygen production rate at that level. If this were the case in the pond, an oxygen deficit would occur in the lower zone due to the respiration of the suspended organism.

Net oxygen production rates were studied in the pond in the late winter, spring, and summer of 1958 (Fig. 4). Each point on the graphs represents the mean of values obtained at four stations within the pond.

Table 2

Light and Dark Bottle Oxygen Production at Different Depths in Junction City Pond 1, August 26, 1958

Time	Depth Inches	% Surface Light Remaining	Approx. Mean Light F.C.	D.O. Change, ppm Light Bottle	D.O. Change, ppm Dark Bottle	Oxygen Prod. ppm/hour Net	Oxygen Prod. ppm/hour Gross	Respiration, ppm per hour
12:15 PM	3	66	2,640	+2.10	-0.85	+1.1	1.5	0.4
to	15	26	1,040	+1.10	-0.85	+0.6	1.0	0.4
2:15 PM	30	7	280	-0.25	-0.85	-0.1	0.3	0.4
	42	1.5	60	-0.50	-0.90	-0.3	0.2	0.5

D.O. determinations were made in triplicate.

Substantial quantities of dissolved oxygen were found to be present under the ice on March 10, 1958 in the upper stratum of water. The gradient dropped off sharply so that no oxygen was detected at 18 inches at any time of the day. Table 21A indicates that on this date (March 10), the euphotic zone, defined as the layer of water in which 99% of the incident light is absorbed, was 10 inches deep. All appreciable photosynthesis is known to occur in this layer. The data clearly show that the oxygen production is confined to the upper one foot of water. At 2 P.M. on this date, the time of maximum concentration of oxygen just beneath the ice, a difference of 17 p.p.m. occurred in the 1½ feet of water. The magnitude of dissolved oxygen change at each depth between sampling periods, however, was not great. A maximum change was observed in the uppermost sample of 2.9 p.p.m. between 11 A.M. and 2 P.M. The concentration at the surface in the early morning sample indicates that the oxygen probably did not completely disappear in this stratum during the night.

The April 15 sampling was done 11 days after the ice cover left the pond. A good supply of oxygen was found at all depths and a sharp gradient did not develop during the day. More than 1% of the incident light was found to remain at the pond bottom, hence, there was sufficient light at all depths for photosynthesis. The sample collected from a depth of 42 inches is close to the compensation level since this point on the graphs changed but little during the day. Concentrations of dissolved oxygen found early in the morning indicate that the pond remained aerobic during the night.

On August 9, the depth of the euphotic zone was 41 inches. The pond at this time exhibited a sharp vertical stratification. During the day, sizeable gains in dissolved oxygen were made only in the upper 1½ feet of water. A difference of 27 p.p.m. between maximum and minimum readings at the surface was observed to occur. The compensation level on this date was slightly below the 27-inch sampling depth. It appears from the data that the bottom sediments were anaerobic on this date, which, plus the effect of vigorous respiratory use of oxygen at this level resulted in marked stratification by late afternoon. At 3:30 P.M., a difference in concentration of 32 p.p.m. was observed in little more than 3 feet of water. The early morning sample indicates that the oxygen did not completely disappear from the pond during the night.

The dissolved oxygen concentrations that were used to construct the graphs in Fig. 4 can be used to estimate the net oxygen gain or loss between the hours of sampling at each depth. The data of August 9 was treated in this manner and the results appear in Table 3.

JUNCTION CITY LAGOON I

DAILY VARIATIONS IN DISSOLVED OXYGEN CONCENTRATIONS AT DIFFERENT DEPTHS ON SELECTED DATES

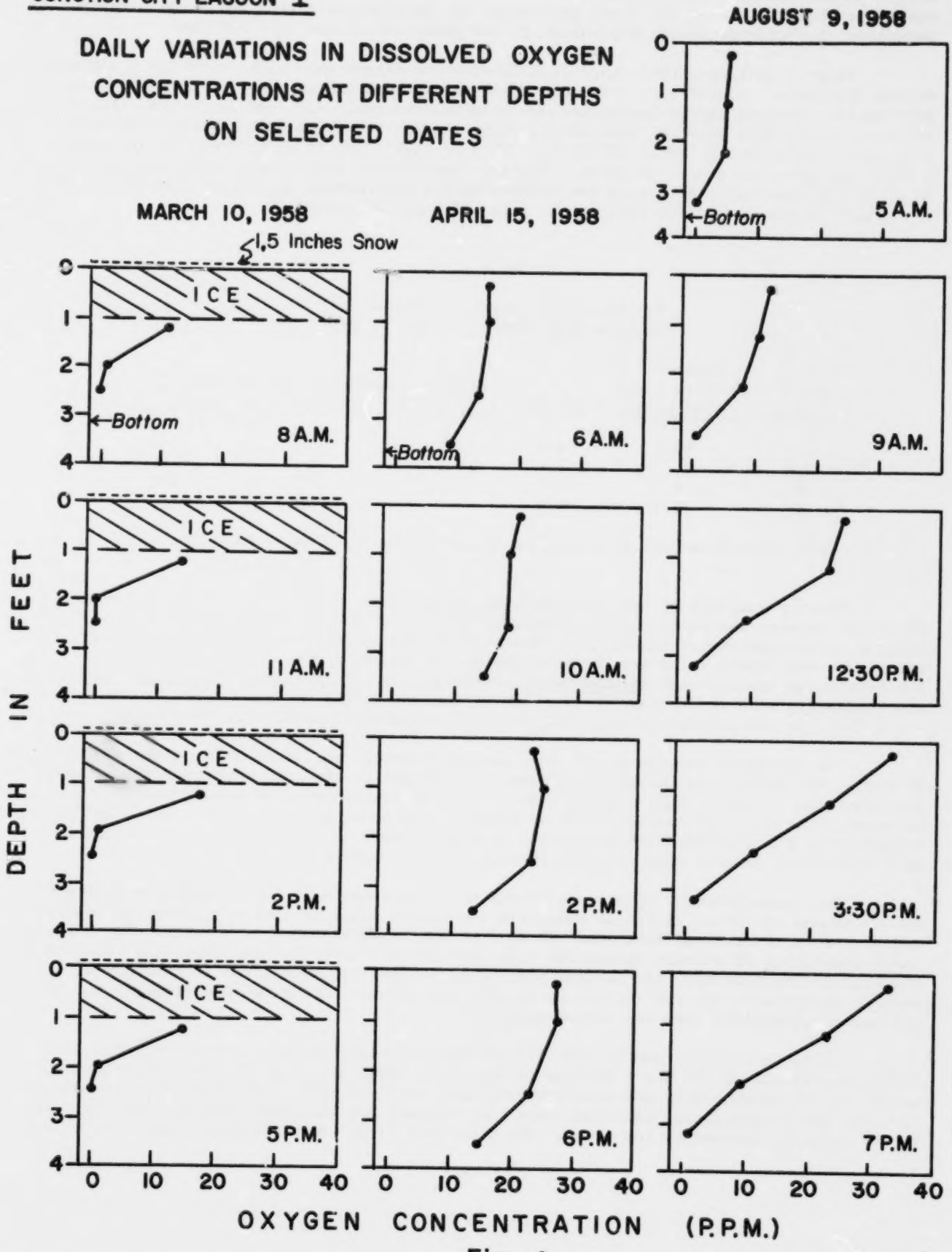


Fig. 4

Oxygen production measured in this manner does not take into account losses at each depth due to respiratory use of the flora and fauna, to the atmosphere when the pond is supersaturated, to diffusion along a gradient in the pond, and to the pond effluent.

Table 3 indicates that there is a decrease in oxygen gain with depth until the middle of the afternoon. In the late afternoon and evening, more oxygen was used than was gained at all levels. Maximum oxygen production was attained between 9 A.M. and 12:30 P.M. Net values obtained during this interval were considerably larger than gross gains measured in bottle experiments later in the month (Table 2). This is partly due to differences in the algae populations present on the two dates. Similar observations can be made using the data of March 10 and April 15. Net gains are largest during the morning and early afternoon, with a decrease in the production rate in the late afternoon and evening.

Table 3

Net Dissolved Oxygen Production in
Junction City Pond 1, August 9, 1958

Depth Inches	Approx. % Surface Light Remaining	Net Oxygen Production, ppm per hour			
		5-9 AM	9-12:30 PM	12:30-3:30 PM	3:30-7 PM
3	69	1.6	3.8	2.5	-0.1
15	16	1.4	3.3	0.3	-0.1
27	4	0.7	0.5	0.4	-0.5
39	1.0	0.2	-0.1	0.3	-0.1

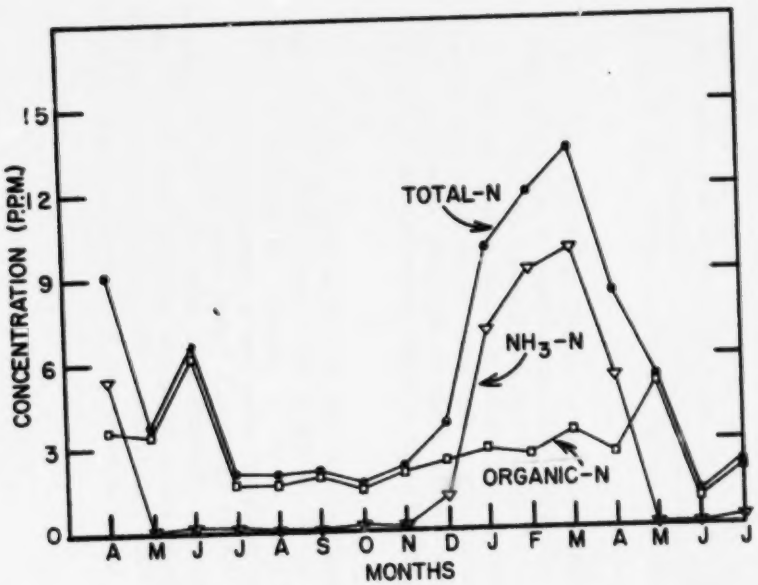
D.O. determinations were made on duplicate samples from 4 stations.

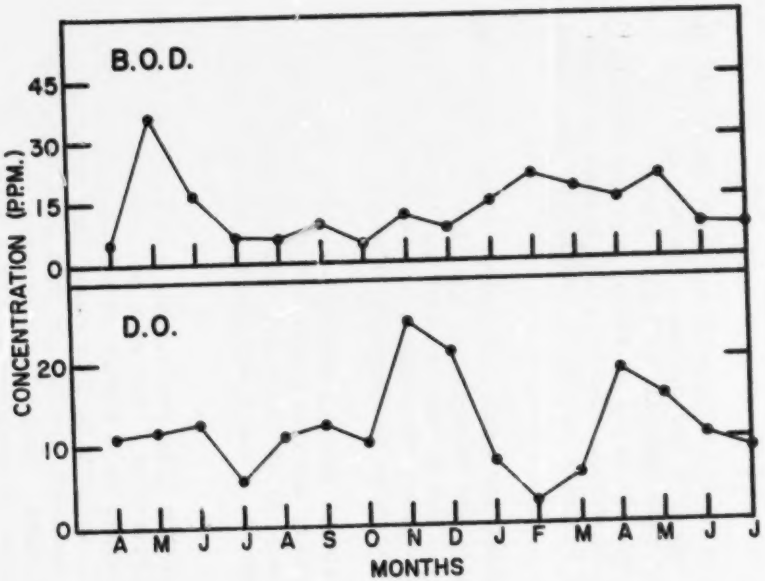
Monthly analyses of the phytoplankton samples from Pond 1 showed only a very general agreement between the number of organisms per milliliter and the algae volume (Fig. 3). On certain of the open-water dates, there was an excellent growth in the pond. On others, the growth was very scant. The growth curve during the period of ice cover from November to March is quite regular with Chlamydomonas predominating. Cryptomonas, Pandorina, Golenkinia, and Chodatella were predominant at one time or another during the warm water period. Table 13A shows that the population was characteristically composed of members of the Chlorophyceae.

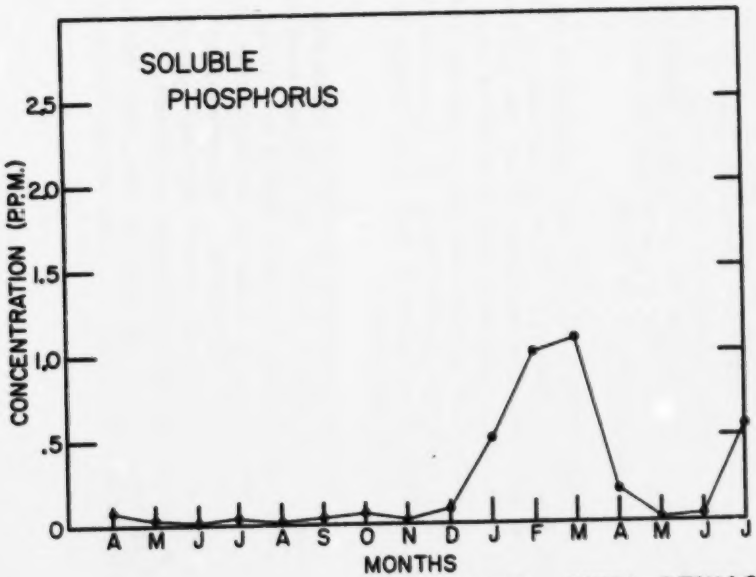
The inorganic nutrients, nitrogen and phosphorus, were often quite scarce in the pond. Nitrates, the product of influent and ammonia oxidation in the pond were scant during most of the open-water period. They reached a maximum concentration of 0.24 p.p.m. under the ice in December. The nitrogen source either as ammonia or nitrate may have been a limiting factor to growth of the phytoplankton during the open-water period. The necessity for a build-up of a sufficient reserve could account for the sporadic appearance of high algae volume.

The inavailability of phosphorus may have contributed to the limited growth observed in the summer of 1957. It can be seen from the curves (Fig. 3) that a build-up in soluble phosphorus in the fall of that year was followed by an algae bloom in October. The relatively large quantities of soluble phosphorus that were present under the ice were diminished by the vigorous spring growths. The maximum phosphorus concentration observed in February at a time when photosynthesis was not sufficient to maintain aerobic conditions was probably due to a release of phosphorus from the bottom sediments.

Close correlation can be observed between the algae volume, organic nitrogen, and B.O.D. curves during the first portion of the study (Fig. 3). The chemical determinations appear to be influenced by the abundance of algae until December. In operation since October of 1956, the stabilization reactions were then exposed for the first time at capacity level to the stresses imposed by ice cover. The dissolved oxygen concentration diminished in the







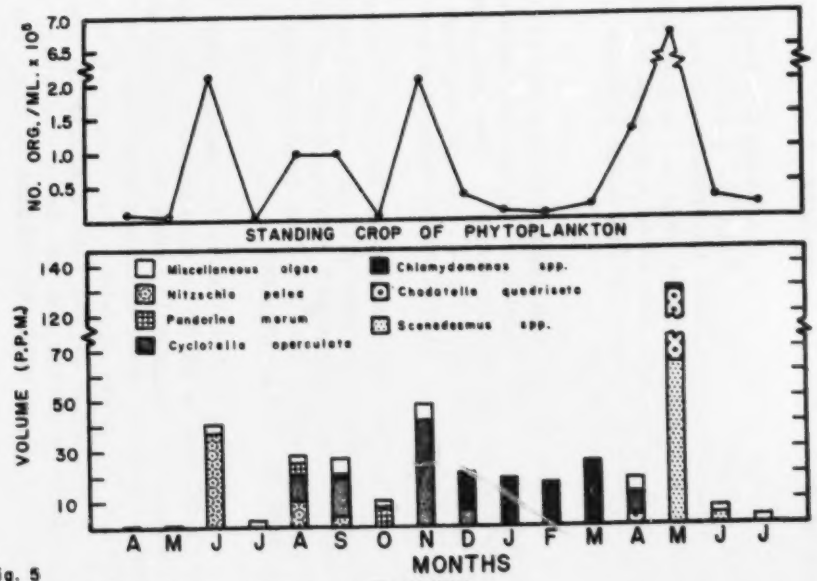


Fig. 5

JUNCTION CITY SEWAGE STABILIZATION POND STUDIES

POND II APRIL 1957 - JULY 1958

pond during January and February. On the latter sampling date, strong odors indicative of anaerobic conditions were evident under the ice. Under these conditions, the influent solids would tend to accumulate.

The chemistry of stabilization pond No. 2 at Junction City (Fig. 5 and Table 3A) is very similar to that of Pond No. 1 with the exception that the extremes are not as high. The nitrogen and soluble phosphorus curves show the same general tendency, however, the organic nitrogen averages only 2.7 p.p.m. for the entire period of study, and the ammonia nitrogen 2.2 p.p.m. attaining a peak of 9.8 p.p.m. in March. The soluble phosphorus curve also attained a peak approximating 1 p.p.m. during February and March, while at other times it was quite low.

The B.O.D. was comparatively steady throughout the entire period of study, averaging 12.8 p.p.m. The dissolved oxygen was supersaturated the majority of the time with the exception of the winter months. The low point of 2.8 p.p.m. was reached the latter part of February. As in Pond No. 1, the pH was high (10.4) during the summer, and reached a low of 7.0 in February. Slight odors were detected from the water in January, February, and March.

The per cent reduction for the 2-stage treatment unit in coliform density was 99.9 for all sampling periods with the exception of February and March when a low of 99.4% was reached. The highest MPN reading occurred on February 25 at which time the effluent of Pond No. 2 tested 49,000. The pond average for Pond No. 1 was 1,457,000 and the pond average for Pond No. 2 was 103,000.

The phytoplankton in the second pond at Junction City was at times similar to that of the first, while on other occasions it was quite distinctive. Two diatoms, species of Nitzschia and Cyclotella, were the predominant organisms on a number of sampling dates (Fig.5). These organisms never attained prominence in Pond 1, indicating that conditions there were not suitable for their growth. The incidence of other dominant species in this pond coincided with an abundance of the same organism in the first pond. Table 14A indicates that the phytoplankton during the course of the study was rather heterogeneous with a number of classes of algae well represented at one time or another.

The relationship between the number of organisms per milliliter and the volume of algae in the monthly samples was in reasonably close agreement in this pond. This is because most of the predominant organisms were of a similar size. The standing crop in Pond 2 was relatively poor throughout the study. A volume of 50 p.p.m. was exceeded on only one sampling date, that being May of 1958. There were occasions when Pond No. 2 appeared more green than Pond No. 1. Its algae volume exceeded that of the latter in June, August, and November of 1957, and in March of 1958.

The effect of the alga population on the chemical characteristics of the water in Pond No. 2 is obscure. This is because of the relatively small abundance of phytoplankton in the pond and the variability of the influent with fluctuating conditions in the first cell. Nutrient nitrogen and phosphorus were present in appreciable amounts only in the winter when alga metabolism was slowed by low temperatures. The only bloom occurred in May of 1958, apparently developing at the expense of the winter reserve of these elements. It can be seen from Figure 5 that this single growth reduced the winter accumulation of nutrients to trace amounts.

The accumulation of bottom sediments was measured in the Junction City ponds in October, 1958 (Table 19A). No samples were found in which there was a sufficient amount of recently settled macroscopic solid particles to measure as an "A" layer. Except for a fine film of well-colored algae at certain stations, the sediment core had a consistent deep black coloration throughout. Microscopically, the cores from both ponds were observed to consist principally of finely divided organic material. Present also were very small numbers of well-colored phytoplankton organisms, the cellulose walls of algae species that were common at one time or another in the pond, and small soil particles. The parent material of the pond bottoms was clay. A mean accumulation of 2.3 cm. was observed in Pond No. 1, and 0.9 cm.

in Pond No. 2. The accumulation was observed to decrease in Pond No. 1, going away from the inlet. An estimated 80% of the pond bottom had sediments deeper than 2.0 cm. The accumulation in Pond No. 2 appeared to be randomly distributed. The ponds had been in operation for two years prior to this measurement.

The penetration of sunlight into Pond No. 1 was measured on several occasions (Tables 20A and 21A). The volume of the pond above the depth at which 1% of the incident light remains is recognized as the zone in which all appreciable photosynthesis occurs. When the pond was covered with ice and snow, only a small percentage of the incident light reached the water. The photosynthetic or euphotic zone was confined to a few inches of water immediately beneath the ice. During the open-water period, the amount of suspended material, principally algae, influenced the pattern of penetration. At times of sparse phytoplankton growth, the entire pond was within the euphotic zone. In May when the population was dense, this zone extended only 1-3/4 feet into the pond. The stratification of algae and sewage solids on certain dates resulted in disproportionate light absorption with depth.

Twenty-four hour surveys were performed on the Junction City stabilization ponds on October 15, 1957 and again on August 19, 1958. The flows on these dates were 16,360 and 15,009 gallons per day respectively. The data collected on October 15 made it possible to calculate the relative efficiency of the ponds as two separate units. Pond No. 1 which received a loading of 12.1 pounds of B.O.D. per 100,000 square feet per day produced a per cent reduction in B.O.D. of 75.4%, total nitrogen 87.3%, inorganic nitrogen 97.5%, and total phosphorus 79% (Table 7A). Pond No. 2 receiving the effluent of Pond No. 1 in turn received a loading of 6.9 pounds of B.O.D. per 100,000 square feet per day. The percentage reduction in this pond for B.O.D. was 72.8%, total nitrogen 60.5%, inorganic nitrogen 50%, and total phosphorus 84.6%. Considering the two stabilization ponds as one unit (Table 8A), the per cent reduction in B.O.D. varied between 97 and 99%, total nitrogen 92 to 96%, inorganic nitrogen 97 to 99%, and total phosphorus 93 to 97%. The effluent contained a maximum of 0.1 pounds of inorganic nitrogen, 0.06 pounds of soluble phosphorus, and 0.6 pounds of B.O.D. per day.

These stabilization ponds also received a light loading of 8 pounds of B.O.D. per 100,000 square feet per day on October 15, 1957, and 20 pounds on August 19, 1958. The higher loading at the latter date undoubtedly represents an increased number of connections to the treatment system.

New Auburn Stabilization Pond

The sewage stabilization pond at New Auburn is 2.7 acres in area, was designed for 160 days' detention, and receives the settled sewage from a population of around 370. Studies were begun on this pond on May 14, 1957 and continued monthly until August 18, 1958.

The chemical data from collected samples is tabulated in Table 4A, and graphically illustrated in Figure 6. The stabilization pond receives a heavier loading than those ponds previously discussed, and, as a result, the concentration of nitrogen, phosphorus, and B.O.D. in the pond is also considerably higher.

Total nitrogen is at its lowest point during the summer and early fall. The concentration rises sharply in late fall and reaches a peak in excess of 35 p.p.m. in February and March, after which it sharply declines to the seasonal low in mid-summer. During the low portion of the total nitrogen curve, the major part of total nitrogen is composed of organic nitrogen which, incidentally, fluctuated very little throughout the course of the study and averaged 6.8 p.p.m. for the entire study. During the peak of the total nitrogen curve, in the winter and early spring periods, the major part of the nitrogen consisted of ammonia nitrogen. Ammonia nitrogen in this pond was very low during mid-summer, but attained a concentration of 30 p.p.m. during February and March. The concentration of nitrites and nitrates was quite low. The trend in soluble phosphorus concentration is very similar to that for total nitrogen. The low point of the cycle is during mid-summer to early fall. In December, there is a sharp increase reaching a peak of 11 p.p.m. in February after which the curve again declines to the summer status. The stabilization pond contained a higher concentration of

soluble phosphorus in June and July of 1958 than it did in June and July of 1957. The average concentration for the entire period of study was 5.8 p.p.m.

The B.O.D. concentration curve is more stable than in those ponds previously discussed. The average for the entire period of study was 35 p.p.m., and, with the exception of the winter months, the pond B.O.D. ranged between 10 and 40 p.p.m. During January, February, and March, however, the B.O.D. rose sharply, and on March 12, a peak of 104 p.p.m. was reached in the stabilization pond. The per cent reduction in B.O.D., based upon grab samples of the influent on the dates sampled, was 85% for the period of study. The range in per cent reduction was 65% on March 12 to 95% in September and October, 1957. During the early part of the study in May and June, 1957, the dissolved oxygen was very low being only a trace in the middle of June. During July, August, September, and October, however, the surface D.O. was above 5 p.p.m. and reached saturation. In November, it began to decline, and during the winter months only a trace was detectable. Toward the middle of March, detectable D.O. was absent but beginning in April there was a sharp increase to supersaturated conditions.

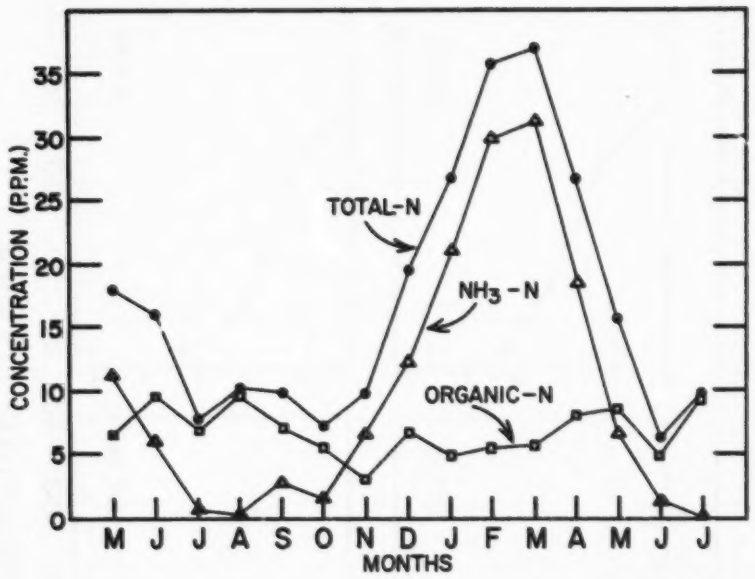
The pH of the stabilization pond fluctuated between 6.9 and 9.7. The lowest reading occurred during February, and the highest readings occurred during the summer months. Ice cover on the pond extended from the latter part of November to April 4, the greatest ice depth being 17 inches. Odors were detectable on the banks of the pond in May and June during the early part of the study and again from the water collected beneath the ice from December through March. Odors were detectable about 4 days after the ice break-up in 1958, but were not detected following that date.

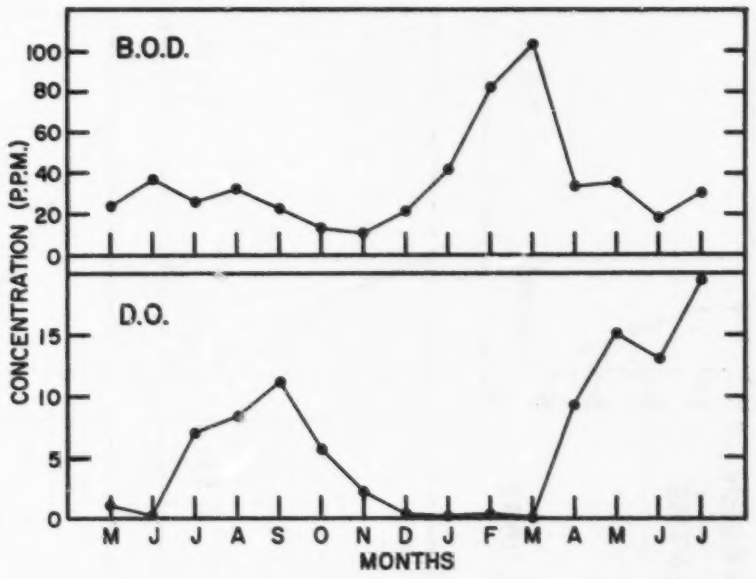
During several times that samples were collected, the lagoon influent was chlorinated in an effort to reduce the odors around the treatment plant. On the occasions when the influent was not chlorinated, samples were collected for the determination of coliform density. On these occasions, the per cent MPN reduction in the stabilization pond ranged from 97 to 99.9. The highest average MPN on a particular sampling date from the stabilization pond was 1,300,000.

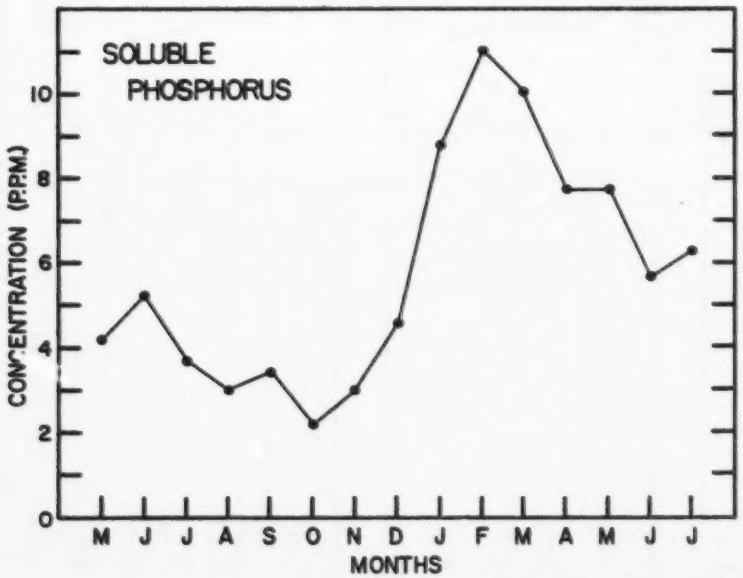
In addition to monthly grab samples from the surface water for the determination of monthly dissolved oxygen levels, a number of dawn-to-dusk observations of the vertical distribution of D.O. were made (Fig. 7). Each point on the graphs represents the mean of four stations within the pond. During the winter, the New Auburn pond became anaerobic and associated odors were easily detectable. By the middle of March, conditions in the pond were still such that the algae present were unable to photosynthesize sufficiently to raise the dissolved oxygen concentration above zero at any time of the day.

Ice cover left the pond on April 4 in 1958, and twenty days later anaerobic conditions had disappeared. Sizeable quantities of D.O. were present during the day, April 24, at all levels. A vertical D.O. gradient did not develop in the pond during the day. The photosynthetic zone extended to a depth of only 20 inches (Table 21A), thus maintenance of a sizeable D.O. concentration at a depth of 4 feet was due to causes other than algal activities. Net D.O. gains were observed at all levels during the morning and early afternoon. In the interval between 2 P.M. and 6 P.M., there was a net loss of D.O. in the pond at all levels. The magnitude of the early morning determinations indicates that the pond was aerobic during the night.

On August 19, 1958, a steep D.O. gradient developed as the day progressed. A difference in the neighborhood of 27 p.p.m. was present in the afternoon between samples taken at 3 inches and 39 inches of depth. The D.O. concentration did not exceed 0.5 p.p.m. during the day at the latter depth. A net gain was observed in the interval between each sampling time in the upper strata during the morning and early afternoon, and diminished at all levels between 3 P.M. and 7 P.M. The euphotic zone on this date reached a depth of approximately 27 inches (Table 21A). Limited photosynthetic oxygen production in the lower portions of the pond, in combination with respiratory use of oxygen moving there from above, are responsible for the stratification. The early morning sample indicates that only the lower portions of the pond were anaerobic during the night.







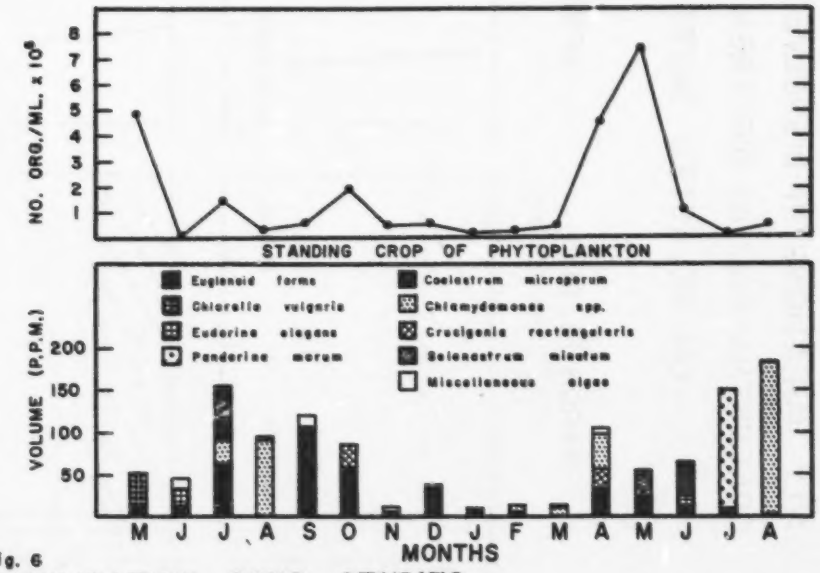


Fig. 6

NEW AUBURN SEWAGE STABILIZATION POND STUDIES

MAY 1957 - AUG. 1958

NEW AUBURN LAGOON

DAILY VARIATIONS IN DISSOLVED OXYGEN CONCENTRATIONS AT DIFFERENT DEPTHS ON SELECTED DATES

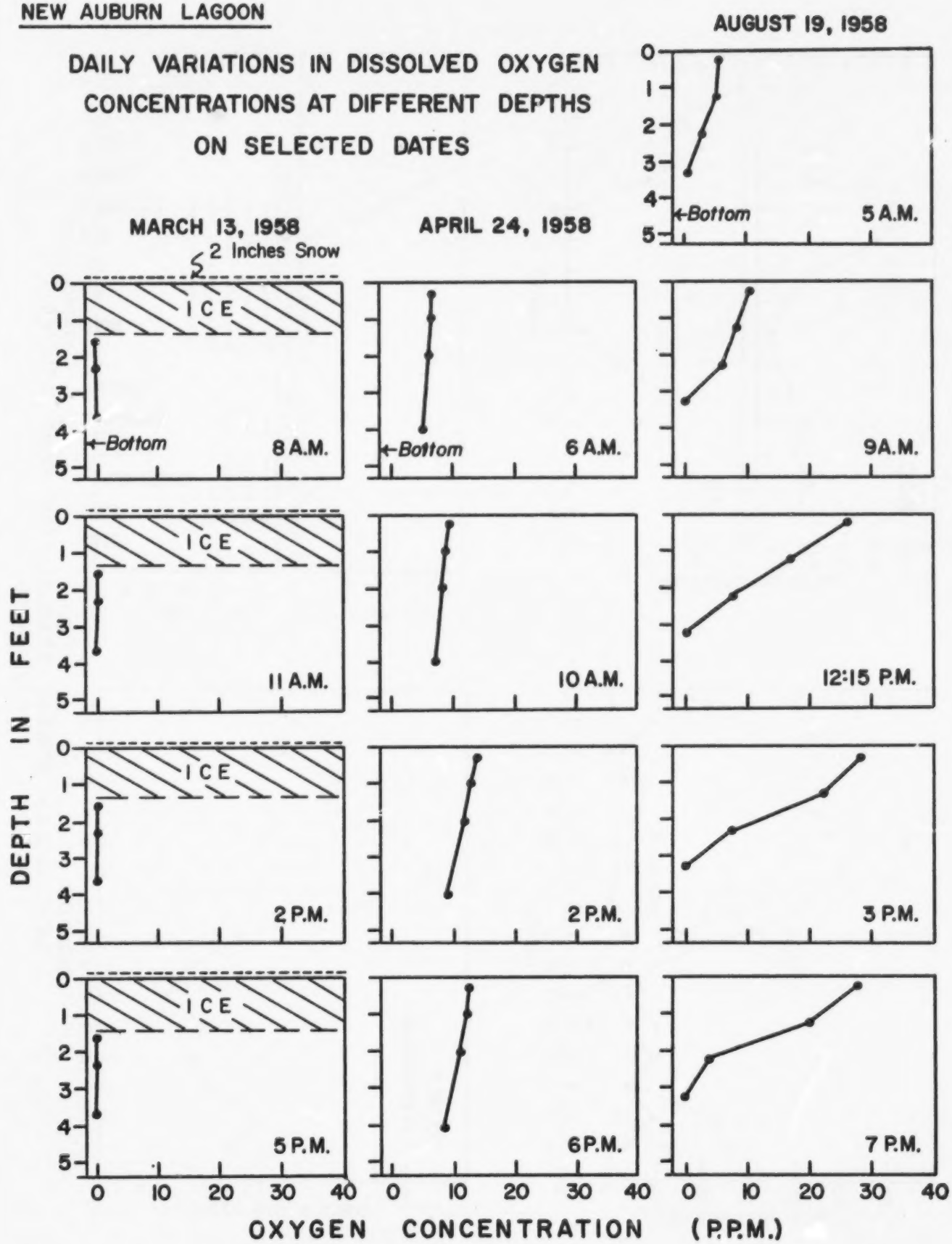


Fig. 7

The phytoplankton population in the New Auburn pond was found to be distinctive in a number of respects. Table 15A shows the euglenoid organisms, species of Euglena, Lepocinclis, Phacus, and Trachelomonas, were found to occur in all of the monthly samples. As a group, these organisms made up a sizeable fraction of the total algae volume in all but three of the monthly samples (Fig. 6). They did not attain such consistent prominence in any of the other ponds. In addition to the euglenoids, Eudorina and Crucigenia were indigenous to this pond. Flagellated organisms dominated the phytoplankton at all times.

A second type of plant growth, species of Lemna (duckweed) and Wolffia (watermeal), occurred during the summer months in the pond. In July and August of 1957 and 1958, rather luxurious growths of these plants were observed. During the day, they were heavily concentrated along the leaward shore spreading out to cover the pond when the wind subsided. This type of flora was not observed on any of the other ponds. The peculiarities of the plant life in the pond suggest that the habitat is somehow distinctive. The most apparent difference between the New Auburn pond and the others is in the type of parent material from which it was constructed. The pond was formed in a marshy area and the bottom and dikes are composed principally of peat. At the other locations, a sand or clay covers the interior of the pond.

The phytoplankton in the monthly samples was observed to fall principally into two classes -- the Chlorophycae and Euglenophycae (Table 15A). The graphic presentation (Fig. 6) illustrates that the total algae volume was reasonably stable during the warm weather months. No outstanding peaks of growth occurred and neither was there an extreme scarcity of algae during the months when the pond was open. It can be seen that the population was considerably reduced under the cover of ice. The number of organisms per milliliter in this pond on a given date bears no relationship to the volumetric measurement of the same date.

Inorganic nitrogen and phosphorus nutrients were never depleted by the growth of pond flora. No relationship as previously described for ponds at other locations can be seen in Figure 6 between the total algae volume and the organic nitrogen and B.O.D. determinations. These tests are influenced at New Auburn by the abundance of organic material in the influent and that contributed to the water by the parent material of the pond, and only secondarily by the total volume of algae present.

Data on the light penetration into the New Auburn pond appears in Tables 20A and 21A. Under ice and snow cover, only a small percentage of the incident light reaches the water. Near the end of the winter period (March 13, 1958), the water in the pond had a very definite gray-black cast being colored presumably by solid materials released from the bottom under existing anaerobic conditions. The small fraction of incident light that did penetrate the ice and snow was absorbed in a distance of less than 1 inch of this water. Light measurements during the open-water period indicated that the depth of the euphotic zone was relatively constant in the pond, being in the neighborhood of 2 feet. The penetration of light at this time is generally limited principally by the abundance of algae. The irregular absorption of light with depth noted on June 18 was due to a noticeable stratification of algae with the population concentrated at a 2-foot depth. The water above this depth was comparatively clear with the light rapidly diminishing between 19 and 25 inches.

A 24-hour survey was performed on the New Auburn sewage stabilization pond on April 8, 1958 and again on August 19, 1958 (Table 9A). On the latter date, there was a reduction in B.O.D. of 88.3%; total nitrogen 78.2%; inorganic nitrogen 98.2%; and soluble phosphorus 58.1%. There was no discharge from the stabilization pond. Unfortunately, at the time of the 24-hour survey in April, no samples were taken from the stabilization pond itself. However, a comparison of these data with visits to the pond during the same month indicate only a slight reduction in total nitrogen (30.2 p.p.m. in the influent compared to 26.6 p.p.m. in the pond). Soluble phosphorus was found at a concentration of 3.7 p.p.m. in the influent and 7.7 p.p.m. inthe stabilization pond. Samples were taken on April 8, 1958 for B.O.D. determination, and the data indicate a reduction of 67.7%.

On April 8, 1958, the flow to the pond was 33,840 gallons per day, and on August 19, 1958 the flow was 15,027 gallons per day. On these dates the respective loading to the stabilization pond, based on the pounds per 100,000 square feet per day, for B.O.D. was 28 and 43, total nitrogen 6.8 and 8.4, inorganic nitrogen 4.8 and 5.5, and soluble phosphorus 0.9 and 1.6.

Spooner Stabilization Pond

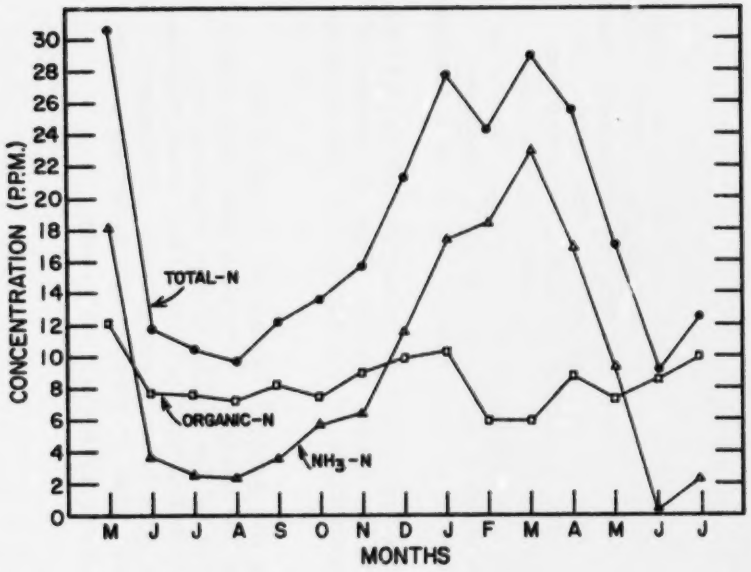
The Spooner sewage stabilization pond receives settled sewage from a community of 3,000, plus milk wastes from a cooperative creamery. It is 22 acres in area, has a detention period of 125 days, and discharges to a nearby river.

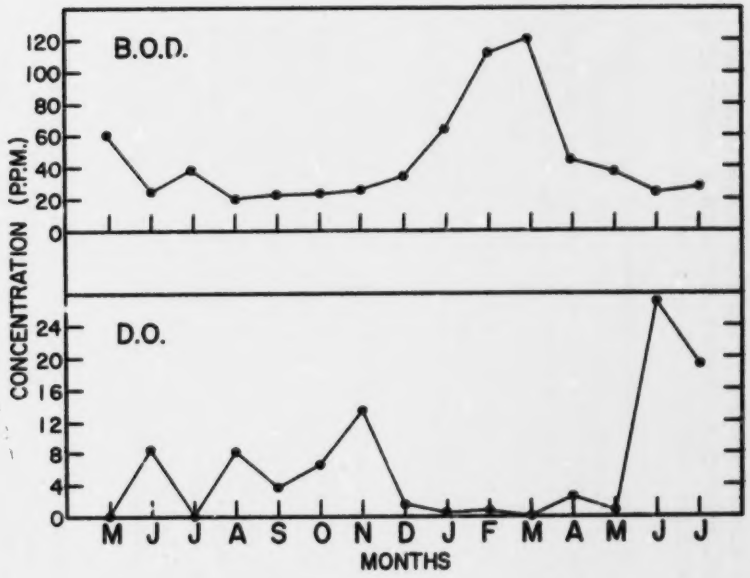
Total nitrogen (Table 5A) exceeded 30 p.p.m. at the onset of the study in May, 1957. Following this, it dropped to a low between 10 and 12 p.p.m. during the three summer months, slowly rising in the fall to a peak approaching 30 p.p.m. in the winter period. The same general trend was then repeated going into the following season. The organic nitrogen curve fluctuated only slightly throughout the study, with the exception of a slight dip in the late winter of 1958, and averaged 8.4 p.p.m. for the complete series. The trend curve for ammonia nitrogen closely followed that of total nitrogen, maintaining low readings during the summer and high readings under ice cover and during early spring. The ammonia nitrogen for the entire period of study averaged 9.5 p.p.m. and attained a peak of 23 p.p.m. in mid-March of 1958.

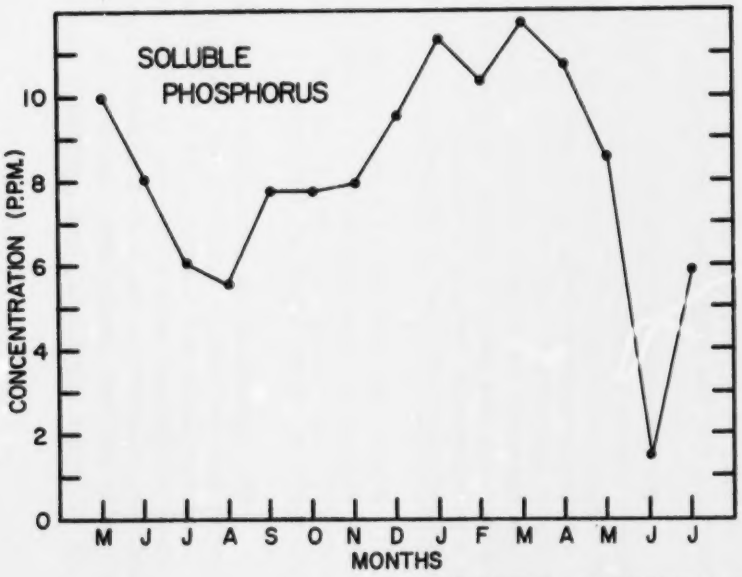
The soluble phosphorus average of 8.2 p.p.m. was the highest of any of the stabilization ponds covered in this study. In May of 1957, it was 10 p.p.m. after which there was a drop to a low of 5.6 p.p.m. near the end of August. Beginning in September, there was a gradual increase in concentration in the pond until a high of 11.8 p.p.m. was reached in mid-March. April and May remain above 8 p.p.m. In June, a drop to a low of 1.5 p.p.m. was noted but in July the soluble phosphorus again rose to 5.9 p.p.m.

The B.O.D. ranged between 20 and 40 p.p.m. in the stabilization pond, with the exception of the winter and early spring period extending from January to the latter part of April. Just before the ice went out, a B.O.D. of 121 p.p.m. was recorded from a composite sample of the stabilization pond. The average B.O.D. for the entire period of study was 45.2 p.p.m. The pickup points for the effluent of the Spooner stabilization pond are located in the four corners of the pond and are raised 18 inches above the bottom. Therefore, the B.O.D. of the effluent are routinely somewhat higher than samples taken 6 inches below the surface. A sample of the effluent in mid-March showed a B.O.D. of 139 p.p.m. The average B.O.D. reduction, based upon grab samples of the influent taken on the routine sampling days, was 86%. The lowest percentage reduction occurred during January, February, and March where a low of 65% was recorded, and the greatest reduction in B.O.D. would appear to occur in July, August, and September with reductions between 90 and 95%. The grab samples of the influent for B.O.D. determination were generally secured around 10 A.M. on the particular sampling dates. The samples for dissolved oxygen were generally secured between 8 A.M. and 10 A.M. on the sampling dates, and the D.O. curve shows considerable fluctuation. During the period of ice cover and extending to the latter part of May, the dissolved oxygen was routinely quite low and in January, February, and March it was well below 1 p.p.m. In August, September, October, and November of 1957, the morning D.O. samples ranged from 3.6 to 13.5 p.p.m., and in June and July, 1958, the dissolved oxygen was super-saturated attaining peaks of 27.0 and 19.2, respectively.

The pH ranged from 7.7 to 11.1. The lowest readings were obtained during the winter period of December to April, and the two highest readings were obtained during June and July of 1958. Otherwise, during the open-water period, the pH remained fairly constant around 8.5. Ice formed on the Spooner stabilization pond the latter part of November and extended until the early part of April, reaching a thickness of 18 inches. The ice went off the pond on April 4, 1958. Odors were detected during the open-water season on May 15, 1957 and again as late as April 29, 1958. Odors were quite strong from the samples collected beneath the ice from mid-December until the ice disappeared.







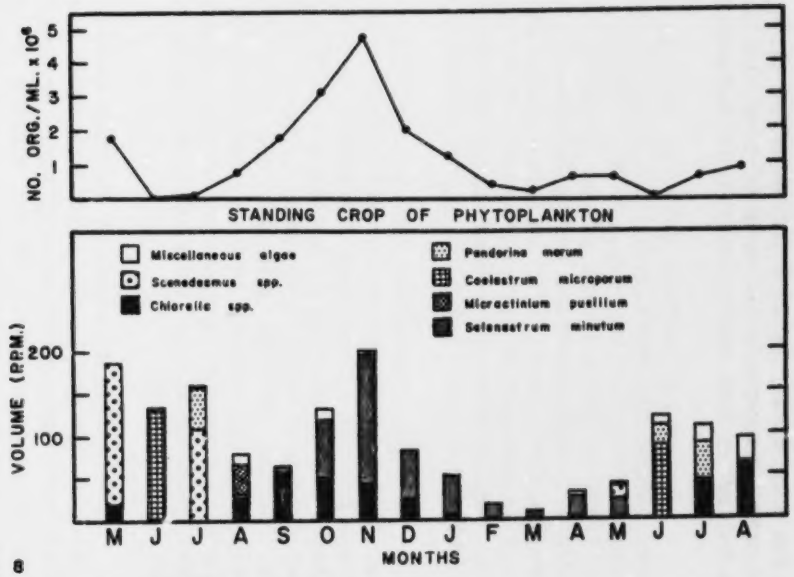


Fig. 8

SPOONER SEWAGE STABILIZATION POND STUDIES

MAY 1957 - AUG. 1958

The measurement of D.O. concentration at various depths throughout the day was begun in the late winter of 1958 and extended through the summer months (Fig. 9). Each point on the curves represents the mean of four stations. The euphotic zone extended to a depth of a few inches in late winter and varied between two and four feet during open water.

In the late winter and early spring, odors in the pond were accompanied by low dissolved oxygen concentrations. On March 15, under the cover of snow and ice, no dissolved oxygen was found at any depth during the day. Minute amounts of D.O. were observed, however, shortly after the ice went out on April 10. At this time, the concentration was observed to decrease from the surface to the bottom. It remained constant throughout the day, never exceeding 0.4 p.p.m. Late in April (April 29), the pond was making moderate net D.O. gains at all levels as the day progressed. The D.O. supply was nearly depleted at 6 A.M. Net gains were made at all levels during the morning and early afternoon while during the interval between 2 and 6 P.M., the curve remained stationary.

The pond recovered from winter stagnation during the month of May. On June 19, the upper 3 feet of water was supersaturated with dissolved oxygen. A very steep vertical gradient was present in the pond throughout the day with differences of between 20 and 30 p.p.m. observed in samples from 6 inches and 4 feet depths. Net gains in D.O. concentration in the upper 3 feet of water were made during the sampling intervals in the morning and early afternoon. During the late afternoon and early evening interval, no appreciable gain or loss was observed. Fluctuations in D.O. concentration at the 4-foot level were relatively small. It appears that oxygen consumption in this stratum was vigorous. The abundance of dissolved oxygen observed in the early morning indicates that aerobic conditions persisted during the night at this time.

The margin by which production exceeded consumption was found to be more slim on August 12. The graphs for this date show that the pond was very nearly depleted of D.O. during the night preceding sampling. Net gains were made in the upper three feet of water in the sampling intervals of the morning and early afternoon. During the evening interval, the water in this layer showed a net loss in D.O. Orly traces of oxygen were found during the day in samples drawn from 4 feet. Water from this depth was gray in color and exhibited odors characteristic of anaerobic conditions. It appears that the phytoplankton in the pond on this date was producing an excess of dissolved oxygen during the day that was not quite sufficient for the night-time respiratory requirements of the biota.

The predominant phytoplankton organisms in the monthly samples from the Spooner pond belonged almost exclusively to a single class of algae, namely, the Chlorophyceae (Table 16A). They composed a relatively stable standing crop. Figure 8 shows that neither tremendous blooms nor extremely scant growths were observed during the periods of open water. The population regularly diminished under the winter ice cover, reaching a minimum in March. Selenastrum minutum appeared to be most tolerant of conditions associated with ice cover. The winter standing crop was made up almost entirely of this species, along with Chlorella. The latter was also common on certain occasions during the warm-water months. Coelastrum, Pandorina, and Scenedesmus occurred in abundance during both summers of the study in one or more samples.

A good correlation is seen in Figure 8 between the number of organisms per milliliter and the volume of algae present in the samples during the winter months. This is because of the consistency during that period of the species composition of the population. No correlation exists at other times of the year.

The phytoplankton population in the pond did not deplete the supply of inorganic nitrogen and phosphorus nutrients at any time during the study. In fact, a luxuriant supply of these nutrients was always available. Fluctuations in the volume of the standing crop of algae at Spooner were hence due to other causes. It has been observed that these fluctuations were relatively small when climatic conditions were optimum for growth. It appears that under optimum conditions, the pond at the present time is capable of supporting a population of given magnitude, and continued fertilization is irrelevant to growth.

SPOONER LAGOON

DAILY VARIATIONS IN DISSOLVED OXYGEN CONCENTRATIONS AT DIFFERENT DEPTHS ON SELECTED DATES

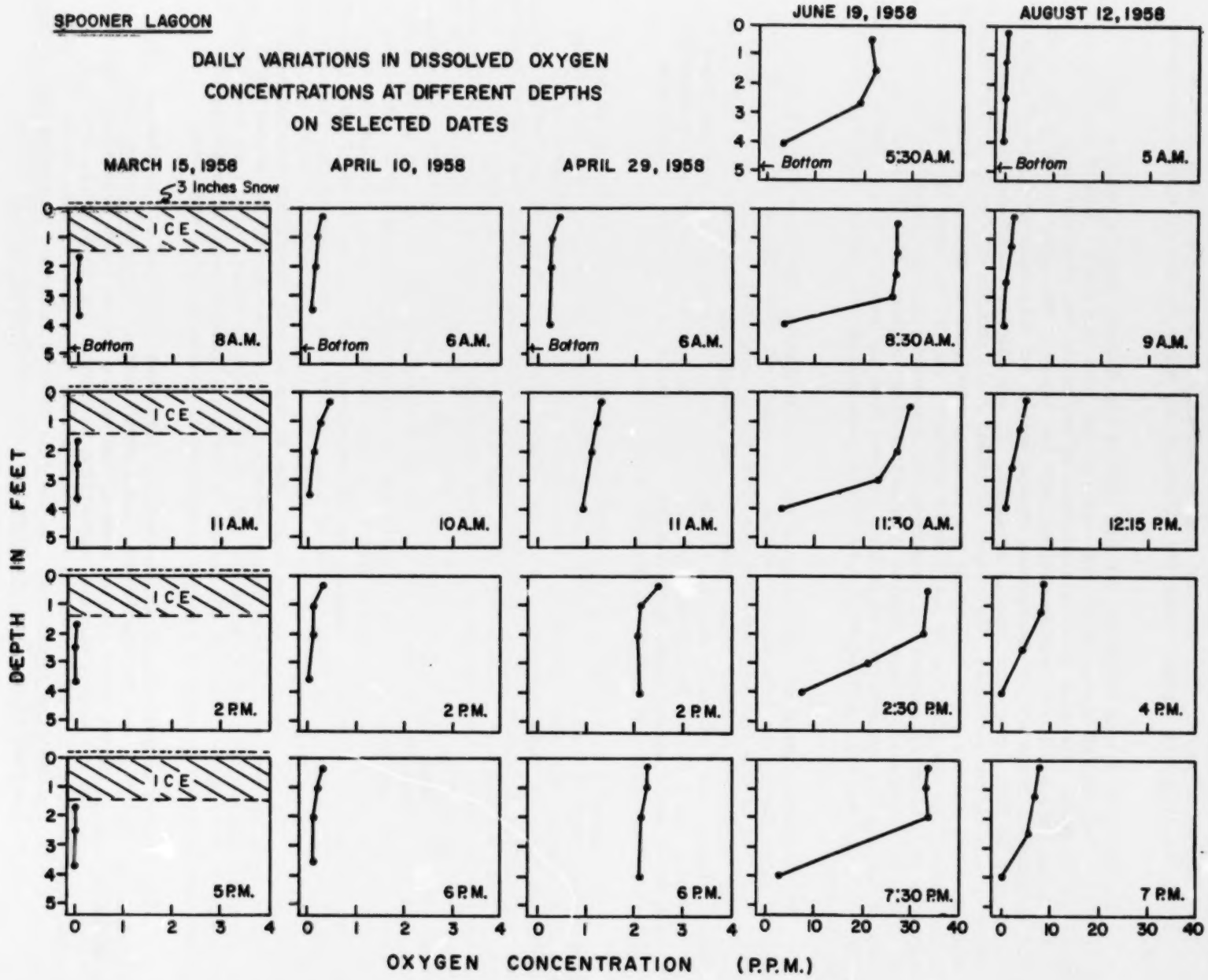


Fig. 9

The laboratory determinations for organic nitrogen and B.O.D. were not influenced significantly by the algae in the monthly samples from Spooner as has been described for certain of the other ponds. The abundant organic material in the influent and its disposition during the different seasons masks the effect of the algae on the laboratory determinations.

The depth of bottom sediments was measured in the Spooner pond in October, 1958 (Table 19A). This was 28 months after the pond was put into operation. Twenty stations were sampled in the pond. The mean total accumulation of sediments was observed to be 4.5 cm. with the total bottom deposit readily divided into two layers. The upper or "A" layer contained macroscopic fragments of decomposing sewage solids and well-colored clumps of algae. The particles in this layer were loosely arranged. It was observed microscopically that in addition to the larger particles, this layer contained small amounts of finely divided black organic material and the empty cell walls and colonial envelopes of species of algae that had been predominant in the plankton at one time or another. The "B" or lower layer had a rather homogeneous deep black appearance. It was observed microscopically to consist of finely divided organic particles. Algae remains were not distinguishable. The "B" layer was compacted, retaining its cylinderical shape when removed from the sampling tube. The lower limit of the sediments was well defined with very little gradation of the organic material into the sandy bottom.

The characteristics of light penetration into the Spooner pond were studied on a number of dates during the late winter, spring, and summer of 1958 (Tables 20A and 21A). Only a small fraction of the incident sunlight was observed to penetrate the snow and ice cover in March. The euphotic zone under these conditions was consequently restricted to a few inches of water. During the open-water season, the depth of this photosynthetic layer was found to vary between 2 and 3 feet. No extreme vertical stratification of suspended solids material was encountered while making these measurements. The figures in Table 21A for each date indicate a rather irregular absorption of light with depth.

Two transects of 10 Ekman dredge samples each were taken from the bottom of the Spooner stabilization pond for the examination of bottom fauna population. The first transect of 10 samples was taken diagonally across the pond, and the second transect of 10 samples was taken at right angles to the first. Thus, a total of 20 individual bottom samples, each representing 36 square inches of bottom area, were carefully examined for bottom-dwelling forms. These samples were collected on three separate dates, October 16, 1957, April 29, 1958, and October 14, 1958. The mean number of bottom organisms per 36 square inches of bottom area (Table 18A) ranged from 161 $\pm$ 35 in October of 1957, to 9 $\pm$ 5 in April of 1958, to 239 $\pm$ 54 in October of 1958. Thus, the estimated population of bottom organisms in the entire stabilization pond ranged from 480,000,000 to 750,000,000 in October of 1957; 15,000,000 to 54,000,000 in April of 1958, and 709,000,000 to slightly over 1,000,000,000 in October, 1958. There was a 94% reduction in population during the winter. A high mortality of blood worm larvae was noted at the time of the monthly samples, as the organisms would die and float to the surface and continually freeze in the bottom layer of ice. At the time of ice break-up, the surface of the water carried large patches of red and white floating bodies of blood worms and phantom midge larvae. The 94% reduction is, no doubt, due to the adverse conditions created by the absence or near absence of dissolved oxygen beneath the ice cover during the winter months. The sizeable increase in population in the fall of 1958 may, no doubt, be due to the build-up of a blanket of sludge material on the bottom of the stabilization pond, thus making the habitat more suitable to support a larger population of bottom-dwelling organisms.

The species composition of bottom-dwelling forms was comprised of the phantom midge, Chaoborus punctipennis, and two species of "blood worm" midges, Tendipes plumosus and T. Tendipediformis. These three species made up the entire bottom fauna population, and in the fall of 1957 the respective species composition percentage was 45.3, 44.1, and 10.6. Samples taken on April 29, 1958 revealed that each of the three species made up exactly one-third of the bottom-dwelling population. In the fall of 1958, however, Chaoborus punctipennis formed 73.6% of the population, Tendipes plumosus 9.6%, and Tendipediformis 15.8%.

Table 4

Comparative Loading and Discharge Data

Pond	Date	Flow	A. Loading - lbs./100,000 sq. ft. per day				B. Discharge - lbs. per day*				C. Percent Reduction in Stabilization Pond			
			B.O.D.	Total N	Inorg. N	Sol. P	B.O.D.	Total N	Inorg. N	Sol. P	B.O.D.	Total N	Inorg. N	Sol. P
Fontana	8-20-58	154,700	5	8.6	7.4	4.8	1.7	5.9	4.4	2.6	88.9	77.4	80.6	82.4
Jct. City	10-15-57	16,360	8	3.6	2.9	0.3	0.1	0.3	0.2	0.01	98.8	92.6	96.9	96.6
	8-19-58	15,009	20	4.5	2.9	0.7	0.6	0.2	0.2	0.06	97.2	96.0	99.3	92.5
New Auburn	4-8-58	33,840	28	6.8	4.8	0.09	10.7	7.5	5.3	1.1	67.7	5.7	6.5	-
	8-19-58	15,027	43	8.4	5.5	1.6	6.0	2.2	0.1	0.8	88.3	78.2	98.2	58.1
Spooner	12-10-57	185,700	55	9.2	4.3	1.4	51.0	28.9	14.6	15.5	90.3	67.2	64.5	-
	8-11-58	300,960	54	7.1	4.1	2.0	70.0	27.6	6.0	13.8	86.4	59.8	84.8	28.4

*Data is theoretical for Fontana and New Auburn, since these ponds do not discharge at present.

It is based upon the pounds of material in influent and per cent reduction in concentration by pond.

A 24-hour survey was conducted on the Spooner sewage treatment system on December 10, 1957 and again during the peak population period on August 11, 1958. On December 10, the flow to the pond was 185,700 gallons per day, and on August 11, 1958 the flow was 300,960 gallons per day (Table 10A). Based upon the 24-hour survey, the per cent reduction going through the pond during the winter period for B.O.D. was 90.3%, total nitrogen 67.2%, and inorganic nitrogen 64.5%. There was no reduction in soluble phosphorus at the time of the December 1957 survey. The lagoon effluent at this time carried 9.4 p.p.m. free ammonia nitrogen, 10.0 p.p.m. soluble phosphorus, and 32.6 p.p.m. B.O.D. On August 11, 1958, the per cent reduction through the pond for B.O.D. was 86.4%, total nitrogen 59.8%, inorganic nitrogen 84.8%, total phosphorus 39%, and soluble phosphorus 28.4%. The stabilization pond effluent at this time carried 2.2 p.p.m. free ammonia nitrogen, 5.5 p.p.m. soluble phosphorus, and 27.9 p.p.m. B.O.D. The nutrients discharged from the stabilization pond were slightly greater in the winter survey than in the one conducted in August. Inorganic nitrogen ranged from 6.0 to 14.6 pounds per day, and soluble phosphorus from 13.8 to 15.5 pounds per day.

The loading to the pond was similar for each survey. The Spooner stabilization pond receives 54 to 55 pounds of B.O.D. per 100,000 square feet per day, 7.1 to 9.2 pounds of total nitrogen, 4.1 to 4.3 pounds of inorganic nitrogen, and 1.4 to 2.0 pounds of soluble phosphorus per 100,000 square feet per day.

DISCUSSION

Conditions encountered in stabilization ponds are directly related to pond loading. This study of four stabilization units gave an excellent opportunity to observe the effects of a gradation in pond loading upon the stabilization mechanism. (Table 4).

The respective B.O.D. loading in pounds per 100,000 square feet per day varied from 5 at Fontana, 10 to 20 at Junction City, 30 to 40 at New Auburn, and 50 at Spooner. Calculated on the same basis, the loadings in terms of nutrient material was much heavier for Fontana than the other stabilization ponds. With the exception of Fontana, the other ponds followed the same general trend as the B.O.D. loading. The pounds of material discharged, or available for discharge per day, ranged from less than one pound of B.O.D. for the 2-stage unit at Junction City up to 70 pounds of B.O.D. and about 15 pounds of inorganic nitrogen and soluble phosphorus for the Spooner stabilization pond.

With the exception of Fontana, the B.O.D. attained in the stabilization pond corresponds very closely to the b.O.D. loading. Pond averages for the entire period of study for Junction City, New Auburn, and Spooner were 21.7 p.p.m., 35.6 p.p.m., and 45.2 p.p.m., respectively. In the second unit of the stabilization pond at Junction City, the average concentration dropped from 21.7 p.p.m. in Pond No. 1 to 12.8 p.p.m. in Pond No. 2. The typical B.O.D. curve for the ponds was low in late summer and early fall, rising in late fall, attaining a peak in late winter, with a gradual reduction in early spring. The peaks obtained ranged from 48.8 p.p.m. at Junction City, Pond No. 1; 103.9 p.p.m. at New Auburn; and 121 p.p.m. at Spooner. The percentage reduction in B.O.D. as the sewage passed through the pond ranged from a low of 65% found during a portion of the winter months to a high in the upper 90's found during more optimum climatic conditions.

As would be expected, the monthly dissolved oxygen curve was coupled very closely with the B.O.D. curve and winter ice and snow cover. Routinely, the dissolved oxygen was high in the summer and fall being reduced to a very low level or eliminated during at least a portion of the winter and early spring. At the Spooner stabilization pond, continuous difficulty was experienced in maintaining dissolved oxygen.

The total nitrogen curve in the typical stabilization pond was high in late winter and spring, and low in summer and fall. With the exception of Fontana, the organic nitrogen made up the bulk of the total nitrogen in the summer and fall. In the winter and early spring period, the ammonia nitrogen became quite high and composed the bulk of the total nitrogen. The stabilization pond at Fontana was the only one in which nitrates were found in appreciable concentration, and these formed the bulk of the total nitrogen except during the January and

Table 4

Comparative Loading and Discharge Data

Pond	Date	Flow	A. Loading - Lbs./100,000 sq. ft. per day				B. Discharge - Lbs. per day*				C. Percent Reduction in Stabilization Pond			
			B.O.D.	Total N	Inorg. N	Sol. P	B.O.D.	Total N	Inorg. N	Sol. P	B.O.D	Total N	Inorg. N	Sol. P
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*Data is theoretical for Fontana and New Auburn, since these ponds do not discharge at present.

It is based upon the pounds of material in influent and per cent reduction in concentration by pond.

February period. Under ice cover the ammonia nitrogen got as high as 12.6 p.p.m. at Junction City, 31.2 p.p.m. at New Auburn, and 23 p.p.m. at Spooner. In general, sewage odors were associated with the water when the ammonia nitrogen got up to 7 p.p.m. or above. The reduction in total nitrogen and inorganic nitrogen as it passes through the stabilization pond appears to be much greater in summer than in winter. In April, at the New Auburn stabilization pond, the reduction was only 6%. This low reduction in nitrogen may have been due in part to the type of bottom material upon which the pond was constructed. The winter reduction in inorganic nitrogen at the Spooner stabilization pond was about 65% compared to about 85% during the summer.

Soluble phosphorus ranged from an average of 0.63 p.p.m. in the Junction City stabilization pond and 1 to 5.8 p.p.m. in the New Auburn pond to 8.2 p.p.m. in the Spooner pond. The pond at Fontana apparently received a much higher loading of soluble phosphorus than did the others but averaged only 2.7 p.p.m. for the entire period of study. Fontana also showed considerable fluctuation in the soluble phosphorus curve. The curves for the other ponds were quite similar, reaching high points in late winter and decreasing in early spring to a low during the summer months. The highest concentration at any time was 11.8 p.p.m. in the Spooner pond. No reduction in soluble phosphorus concentration was found under conditions of heavier loading during the winter and early spring months. Reductions in August ranged from 28% at Spooner to 58% at New Auburn.

The nutrients found in the stabilization ponds were supporting a tremendous quantity of algae (e.g. 9 tons on the average for Spooner). The nutrients are removed from solution and concentrated in algae cells. Many of these die, sink to the bottom, and undergo varying rates of decomposition and nutrient liberation. Phosphorus is precipitated in the presence of dissolved oxygen and alkaline pH during the summer period. When there is a lack of oxygen in the sediment and the pH drops to near normal, the phosphorus can be freed and returns to solution. This causes a higher soluble phosphorus concentration in the pond during winter than is found in the influent to the pond.

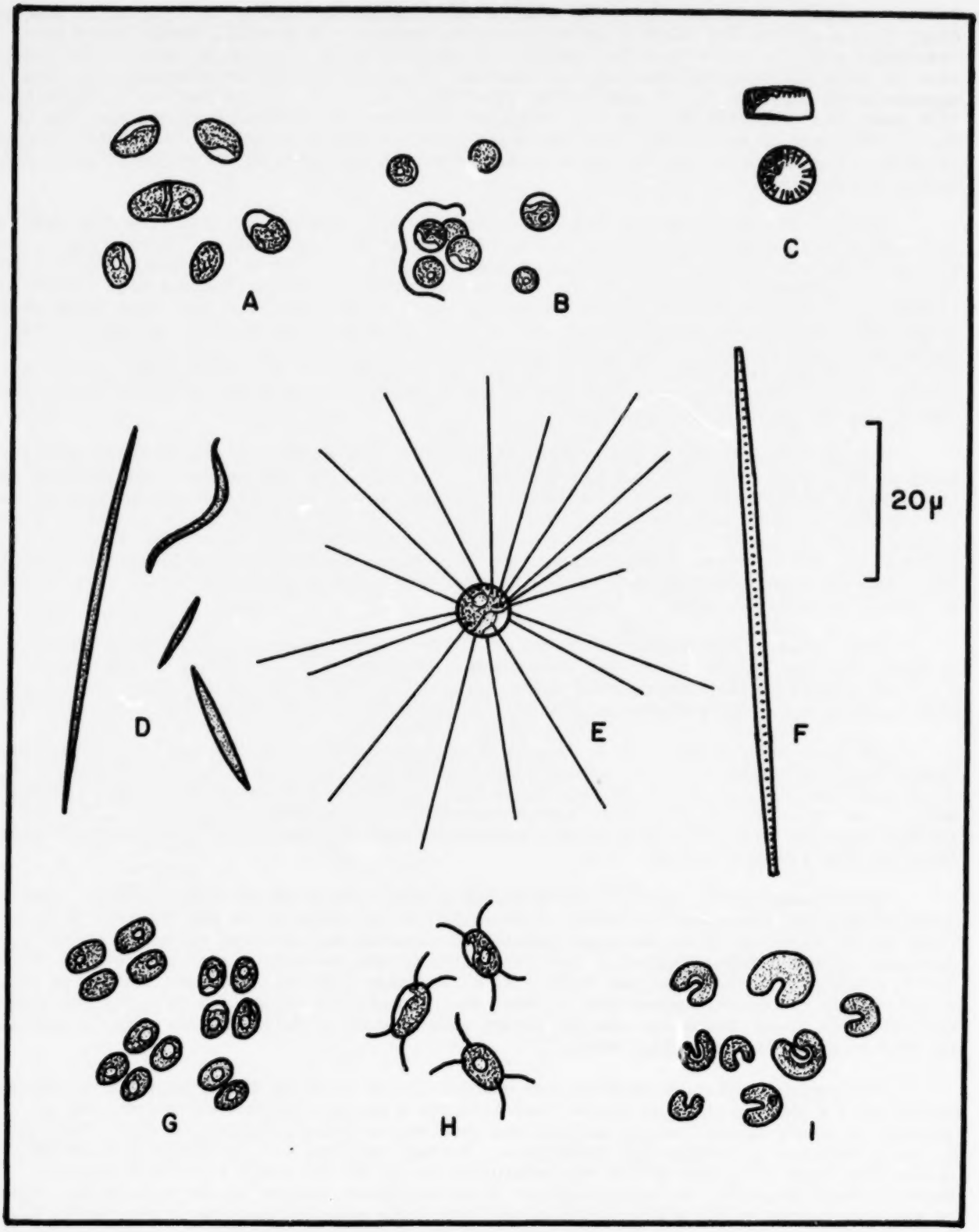
Oddly enough, the lowest reduction in coliform organisms occurred in the Fontana stabilization pond during the latter part of January. This was 64%. Excluding a reduction of 80.8% on June 25 in the Fontana pond, and a reduction of 78.5% on January 21 in the Spooner stabilization pond, the reductions were all in the upper 90's and many were as high as 99.9%.

The vertical distribution of dissolved oxygen in ponds receiving raw or settled sewage varied with the season. In late winter under the cover of snow and ice, the ponds were either completely anaerobic or the dissolved oxygen was confined to a thin layer of water immediately beneath the ice. Strong odors were always associated with anaerobic conditions. The upper stratum of water in a pond could be well oxygenated and odorless, while the lower D.O.-poor layer smelled strongly of H_2S.

Odors issued forth from the ponds during a short period in the early spring. Their duration was dependent upon the rate of reaeration of the water which was governed principally by the speed at which the algae population expanded and produced oxygen. The vertical dissolved oxygen studies indicated that the length of the recovery period was related to the B.O.D. loading. The water in the first pond at Junction City was super-saturated with D.O. at all levels eleven days after the ice went out. Comparable quantities of dissolved oxygen were observed at all levels in the New Auburn pond 20 days after it opened. The Spooner pond recovered in approximately four weeks.

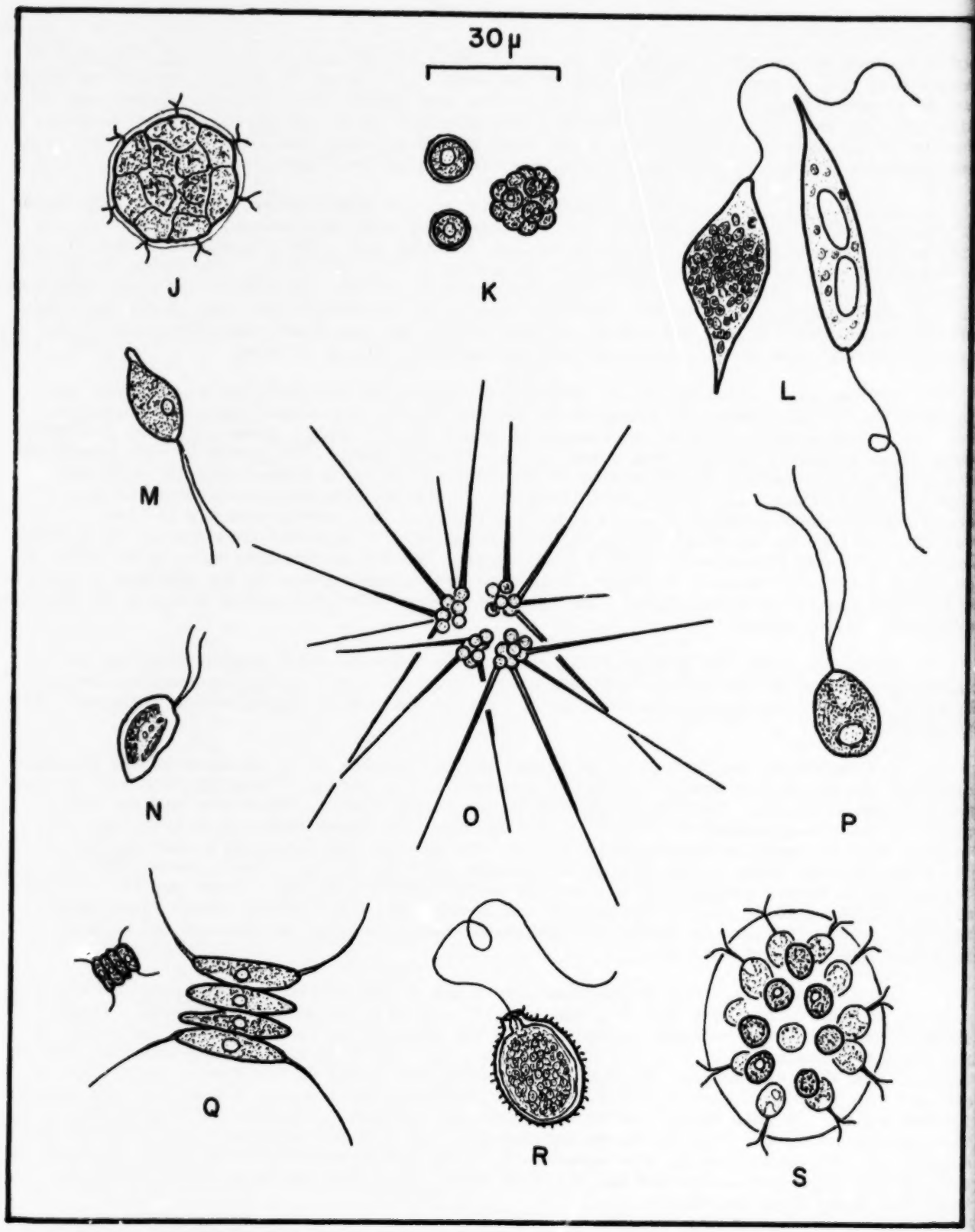
The spring studies of dawn-to-dusk changes in the vertical distribution of dissolved oxygen in the pond resulted in curves that indicate a uniform concentration from top to bottom. No sharp stratification of D.O. was observed to develop during the day. This was in sharp contrast to summer-time conditions. A steep vertical D.O. gradient with bottom values near zero developed as the day progressed in all of the ponds studied during the summer. These seasonal differences appear to be caused by changes in the respiratory demands of the pond bottom at different times of the year. The respiration rate approximately doubles for each 10° rise in temperature. The mean mid-day bottom temperatures in April for the three

SEWAGE STABILIZATION POND ALGAE



A. Chlorella ellipsoidea. B. Chlorella vulgaris. C. Cyclotella operculata.
D. Ankistrodesmus spp. E. Golenkinia radiata. F. Nitzschia palea.
G. Crucigenia rectangularis. H. Chodatella quadriseta. I. Selenastrum minutum.

Fig. 10



J. Pandorina morum. K. Coelastrum microporum. L. Euglena spp.
M. Chlorogonium euchlorum. N. Cryptomonas erosa. O. Micractinium pusillum.
P. Chlamydomonas sp. Q. Scenedesmus spp. R. Trachelomonas sp.
S. Eudorina elegans.

Fig. 11

ponds studied was 10.5°C. In August, it was 23.0°C. On the basis of temperature alone, the respiratory use of oxygen at the bottom of the ponds would hence be doubled. Dissolved oxygen moving downward from the photosynthetic layer was very rapidly consumed under conditions of high temperature. This seasonal difference was observed in all of the ponds, and was independent of measured variables such as the depth of the euphotic zone, the degree of pond mixing under the influence of surface winds, and the size of the algae population.

By using a light and dark bottle technique, it was demonstrated that oxygen production diminishes in the ponds with depth. The photosynthetic rate decreases in proportion to the intensity of solar radiation. The down-to-dusk vertical D.O. curves demonstrate that the photosynthetic rate differs at each depth according to the time of day. In nearly every instance where net gains were made, these were greatest during the morning and early afternoon. In the late afternoon and evening, the ponds typically exhibited a net loss of oxygen. The photosynthetic rate diminished during a period of the day when there was sufficient light, indicating that some other limitation had been imposed upon the process.

Considerable variation in the qualitative aspects of the flora was found among the ponds. The primary producing community at Fontana through the second winter of operation was the phytoplankton dominated by species of green algae. In the summer of 1958, a filamentous algae submerged aquatic weed community gained ascendance. The growth of this community was observed to commence at the bottom of the pond in the early summer when the plankton population was sparse and light penetration was excellent. Chlorophyceaen phytoplankton dominated the first pond at Junction City at all times. The second pond was at times qualitatively similar to the first, while on other occasions it supported good growths of diatoms. Aquatic weeds and filamentous algae did not occur. The New Auburn pond had a good growth of duckweed during the summer. Euglenoid organisms were always common in the plankton in association with species of green algae. The flora at Spooner consisted almost entirely of planktonic species of green algae.

Table 17A lists the genera of algae that were found in water samples from the ponds during the course of the study. The similarity among the ponds in this respect is striking. Figures 10 and 11 are camera lucida reproductions of the common phytoplankton organisms drawn to scale.

The volume of the phytoplankton in the monthly samples is an estimate of the standing crop and can be used to compare primary production in the ponds. Production was high in summer and low in winter. The winter population was fairly stable, reaching a minimum just prior to the disappearance of the ice in the spring. The ponds receiving a light influent loading such as those at Fontana and Junction City have an unstable summer-time population. The standing crop tends to be alternately massive and then sparse. Blooms were commonly diminished to meager proportions in the four weeks between sampling. Ponds receiving a moderate influent loading such as New Auburn and Spooner had a relatively stable warm-weather standing crop. Differences during the open-water season between the minimum and maximum monthly crops were not extreme.

The mean standing crop at Junction City 1 and 2, New Auburn, and Spooner, for the periods of open water, were 103, 26, 101, and 107 p.p.m. by volume, respectively. Using these values as a mean estimate of the crop in the upper three feet of water, the ponds on the average contained 0.7, 0.1, 1.1, and 9.6 tons wet weight of algae, respectively. Similar calculations from the monthly determinations during the period of ice cover resulted in an average crop of 0.2, 0.1, 0.2, and 6.6 tons at Junction City 1 and 2, New Auburn, and Spooner in that order. On this basis, the Spooner pond was the most productive followed by New Auburn, then Junction City 1. This is the descending order of influent nutrient loading to the ponds. Fontana was not considered in this comparison, since the probability of seasonal predator control on the algae population and the shift in flora during the second summer of the study set this pond apart from the others.

The appearance of the surface of the ponds in open water seasons was not displeasing to the eye. Nuisances resulting from surface decomposition of plankton or sewage solids did not occur. The filamentous algae at Fontana rose to the surface in late summer and turned

brown. The leaward shores of the ponds commonly had a scant concentration of suspended debris confined to a small area. Ducks found the habitat suitable and frequented the ponds often. Frogs, turtles and a variety of invertebrate animals thrived in the water.

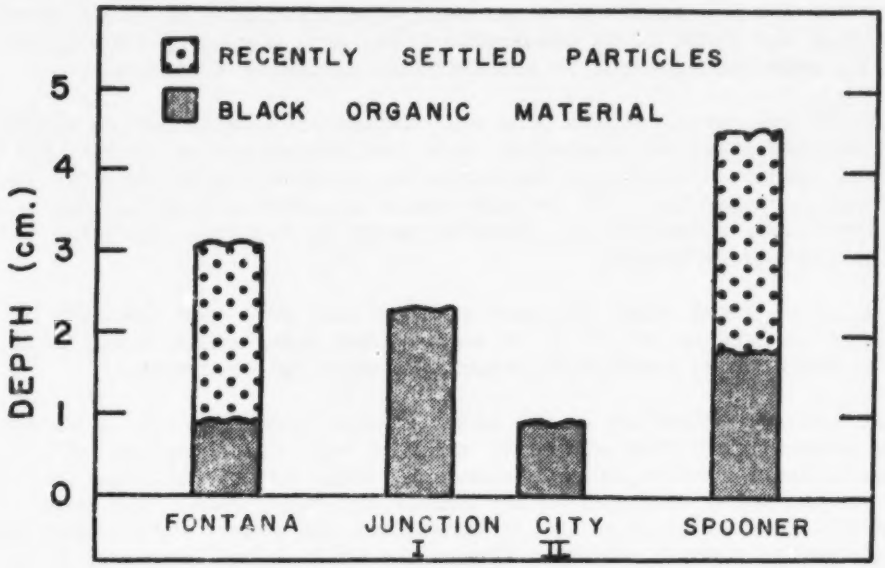


Fig. 12
SEDIMENT ACCUMULATION - FALL '58

A sizeable quantity of sediment accumulated on the pond bottoms during the first two years of their operation (Fig. 12). Suspended particles of the influent and the organisms growing in the pond settled to the bottom. Here they were broken down, eventually losing their microscopic identity. The more stable remains persisted as a layer of finely divided amorphous material that assumed a deep black coloration. Figure 12 illustrates the differences that were found between the ponds sampled. The sediment cores were taken in October, at the end of the open water period. They represent the residual the ponds were unable to oxidize under the best dissolved oxygen and temperature conditions. At Junction City, the macroscopic bits of sewage solids and algae deposited during the preceding months had been broken down by the time of sampling. An accumulation of these materials above the finely divided black organic layer was evident at Fontana and Spooner.

Ice covered the ponds from late November to early April. During this period, it was commonly overlain with snow. Under these conditions, the transmission of incident light to the water below was very poor. The euphotic zone in the winter was confined to a few inches just beneath the ice. In ponds receiving raw or settled sewage, the depth of this zone varied between two and four feet during the open season, depending upon the concentration of suspended material. All appreciable photosynthesis is hence confined to a relatively thin layer of water. For purposes of comparison, similar light measurements were made in two Wisconsin lakes. The data appear in Table 21A. At the time of measurement, the euphotic zone in Lake Waubesa, near Madison, Wisconsin, extended to a depth of approximately 18 feet. A good growth of Microcystis was present. In Pine Lake, near Waukesha, Wisconsin, 1% of the incident light remained at a depth of approximately 64 feet. Plankton growth was sparse. The complex metabolism of fresh-water biota as known in lakes is vertically compressed in sewage stabilization ponds.

SUMMARY

1. A 15 month chemical and biological investigation was made of existing sewage stabilization ponds in Wisconsin. These received raw sewage, settled sewage, and trickling filter treated sewage at loadings ranging from 5 to 55 pounds of B.O.D. per 100,000 square feet per day. The efficiency of these ponds at this latitude was found to be comparable with, and, during optimum climatic conditions, somewhat superior to conventional secondary treatment.

2. The B.O.D. in the stabilization pond was characteristically low in summer and fall, increasing after ice formation to a high concentration in late winter and spring. Maximum B.O.D. concentration was governed principally by loading. B.O.D. removal ranged from 65% in late winter to about 90% during the summer months. No B.O.D. reduction was found to occur in the pond receiving trickling filter treated effluent.

3. Reductions in coliform organisms were greater than 98%, more than 87% of the time. There is greater reduction in summer than under winter conditions, and, except for one sample, summertime reductions were 99% or greater.

4. Total nitrogen concentration in the stabilization ponds was low in summer and fall, and highest in winter and early spring. With the exception of the pond receiving effluent from secondary treatment, total organic nitrogen made up the bulk of the total nitrogen in the summer and early fall. The organic nitrogen content fluctuated very little throughout the year. During the winter and early spring, ammonia nitrogen formed the bulk of the increased total nitrogen concentration reaching a high of 31 p.p.m. Under heavier loadings, ammonia nitrogen was present in small amounts during the summer period. At Fontana, nitrate nitrogen was prevalent and formed the bulk of the total nitrogen concentration with the exception of January and February. The per cent reduction under higher loadings in inorganic nitrogen was found to be about 65% in winter compared to 85% in summer. Lower loadings produced greater reductions.

5. The soluble phosphorus concentration was lowest in summer and fall, and highest (maximum 11.8 p.p.m.) in late winter. There is an indication that precipitation occurred in summer in combination with alkaline pH and increased D.O. In winter under conditions of near neutral pH and no D.O., soluble phosphorus was liberated from the bottom deposits. There was no reduction during the winter period. Summertime reductions ranged from 28% to 58% or higher dependent upon loading. There is some indication that a two-pond system in series is more efficient in soluble phosphorus removal than a single stage unit.

6. Dissolved oxygen is, of course, closely associated with B.O.D. Stabilization ponds were aerobic during summer and fall but contained very little, if any, D.O. during ice cover and early spring. Vertical D.O. was typically homogenous during spring (April), becoming strongly stratified during summer, with anaerobic conditions near the bottom. Photosynthetic oxygen production diminishes with depth in proportion to the intensity of solar radiation. In warm weather, it fluctuates diurnally with maximums in the morning and early afternoon.

7. Odors were associated with prolonged anaerobic conditions. Under B.O.D. loadings up to 20 pounds per 100,000 square feet per day, no odors were detected in the vicinity of the pond during open-water conditions. With a B.O.D. loading of 25 to 40 pounds per 100,000 square feet per day, odors were detected for a period of about two weeks in the vicinity of the pond after the ice went out. Odors up to four weeks in duration were associated with B.O.D. loadings of 50 to 60 pounds per 100,000 square feet per day.

8. Algae production was generally high during open water, decreasing under ice cover and reaching a minimum in March. Less fluctuation in production was associated with higher nutrient loadings in ponds receiving raw or settled sewage. The concentration of nitrogen and phosphorus in the pond did not appear to limit production. Phytoplankton plays a major role in the reduction of nutrients in the waste water through assimilation and eventual deposition in the bottom sediments.

9. The depth of the euphotic or photosynthetic zone in ponds receiving raw or settled sewage varied between two feet and four feet during open water depending principally upon the abundance of phytoplankton. In winter, the depth at which 1% of the incident light remains is governed by the amount of snow and the quality of the ice. Sufficient light penetrates a few inches of snow and one or two feet of ice so that sizeable quantities of photosynthetic oxygen may occur in the ponds in winter.

10. Solids settle to the bottom and are utilized in the anabolic functions of the benthic organisms. Decomposition during the season of optimum temperature and dissolved oxygen is inadequate to completely oxidize this material. Partially decomposed material tends to accumulate. This layer of sediment may exert an oxygen demand on the superimposed water causing extreme vertical D.O. stratification in summer.

11. Bottom organisms in the Spooner stabilization pond were confined to three species of midges whose combined population ranged from 36 per square foot in the early spring to 956 per square foot in late fall. There was a 94% reduction in population caused by anaerobic bottom conditions over the first winter of study. This tremendous population of benthic forms during the open water period and their subsequent mortality during late winter undoubtedly enters into the nutrient cycle and contributes to a greater nutrient reduction in summer than is found in winter and early spring. Those larvae which assimilate nutrients indirectly through feeding on phytoplankton and subsequently pupate and develop into adults, completely remove their share of nutrients from the pond. Those larvae which do not pupate but are killed by winter anaerobic conditions delay the re-entry of their share of nutrients into the superimposed water until late winter or early spring.

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Table 1A

Chemical Summary - Fontana Sewage Stabilization Pond

Dates (1957-1958)	3-26	4-18	5-27	6-27	7-29	8-29	9-30	10-24	12-2	12-26	1-30	3-4	4-1	6-25	7-22	Ave.
Composite Pond Sample (ppm)(6)*																
Organic Nitrogen	5.4	7.0	6.8	5.2	1.8	1.5	3.4	1.8	1.6	5.0	4.0	3.2	3.8	0.8	1.7	3.5
Ammonia Nitrogen	1.6	0.6	0.2	0.1	0.8	0.6	0.2	0.2	0.2	1.8	16.8	6.8	1.0	0.5	0.6	2.1
Nitrites	0.1	0.2	0.1	0.2	2.0	0.4	0.1	0.2	0.1	0.2	0.1	0.2	0.7	0.5	0.6	0.3
Nitrates	1.6	2.9	0.4	1.2	4.2	9.9	8.2	11.5	14.0	5.8	0.2	4.9	4.4	7.2	5.0	5.4
Soluble Phosphorus	1.6	1.5	0.3	0.2	4.6	4.8	0.5	3.3	2.8	3.0	6.2	4.3	2.0	1.6	3.1	2.7
Total Solids	426	550	482	420	540	566	492	504	554	462	548	472	434	490	550	499
Suspended Solids	62	120	95	57	9	19	47	14	27	58	25	20	36	4	34	42
M.P.N. (x 10^3)																
Influent					1,700	1,400	460.0	170.0	2,800	7,900	4,900	1,400	1,700	13.0		
Pond Average (3)*					1.4	1.9	0.2	16.0	6.0	13.7	1,760	10.5	3.9	2.5	4.4	
% Reduction					99.9	98.6	99.9	91.0	99.8	99.8	64.1	99.3	99.8	80.8		
B.O.D. (p.p.m.)																
Influent			7.5	14.4	22.1	17.6	10.6	4.4	22.1	22.3	41.1	11.2	21.3	16.6		17.6
Pond Average (5)*	38.6	32.9	29.9	22.3	4.4	6.3	17.0	8.1	11.3	31.8	27.4	15.3	31.7	3.8	6.3	19.1
D.O. (ppm) Ave. (5)*	20.0	20.7	15.8	19.7	3.1	7.5	24.5	8.8	36.2	32.6	2.0	16.8	28.7	12.1	13.4	
Temperature Ave. °C.	2.5	14.6	15.5	24.5	26.5	21.0	16.0	9.0	2.5	2.0	0.5	0.7	9.5	20.0	23.5	
pH Average	8.8	9.0	9.4	9.9	8.3	8.8	10.2	9.3	9.3	9.1	7.8	7.6	9.5	9.1	8.8	
Ice Cover (Inches)									3	1	10	12				
Odor Detected											x					

*Number of Stations Sampled to Obtain Average

Table 2A

Chemical Summary - Junction City Sewage Stabilization Pond No. 1

Dates (1957-1958)	5-14	6-18	7-15	8-20	9-24	10-15	11-25	12-17	1-20	2-25	3-11	4-15	5-20	6-16	7-24	Ave.
Composite Pond Sample (ppm)(6)*																
Organic Nitrogen	5.0	3.2	2.0	3.0	3.6	5.4	2.8	5.4	4.2	3.4	5.3	8.6	6.6	1.6	3.6	4.2
Ammonia Nitrogen	.07	.17	.20	1.3	.53	.33	4.6	6.8	12.0	12.6	9.4	5.3	.06	.06	.12	3.6
Nitrites	<.01	<.01	<.01	.02	.05	.02	.02	.03	.01	.03	.05	.30	<.01	<.01	.06	.02
Nitrates	<.3	<.2	<.3	<.1	.15	.08	.2	.24	.03	.12	.12	.32	<.08	<.08	<.08	.16
Soluble Phosphorus	.02	<.01	.09	.52	.92	.64	.76	1.16	1.1	2.75	1.0	.41	<.01	.09	0.6	0.63
Total Solids	278	268	252	306	314	342	332	378	376	308	286	280	328	258	310	308
Suspended Solids	49	49	20	28	24	39	18	34	31	40	43	34	84	18	35	36
M.P.N. (x 10^3)																
Influent			49,000	130,000	130,000	4,700	240,000	1,400	4,900	7,900	17,000	13,000		17,000	54,000	
Effluent (Pond #2)			>2.4	1.3	0.5	.09	.1	.05	1.7	49.0	26.0	.79	>.02	.004	1.3	
% Reduction			99.9	99.9	99.9	99.9	99.9	99.9	99.9	99.4	99.8	99.9		99.9	99.9	
Pond Average (3)*			.5	20.0	64.0	6.7	18.6	5.1	124.0	1,457	64.0	25.3	.07	.007	2.7	
B.O.D. (p.p.m.)																
Influent			126.0	80.4	329.0	51.5	462.0	52.4	129.0	194.0	105.0	77.5		105.0	129.0	153.0
Effluent (Pond #2)			5.5	5.1	8.9	6.6	7.6	3.9	11.6	16.9	21.3	10.4		7.0	6.5	9.3
% Reduction			96.0	94.0	97.0	87.0	98.0	93.0	91.0	91.0	79.0	86.0		93.0	94.0	93.0
Pond Average (3)*	48.8	19.8	7.8	12.7	20.5	26.7	10.0	15.5	20.0	42.8	26.0	16.3	17.2	14.0	26.8	21.7
D.O. (ppm) Ave. (3)*	9.8	14.4	11.1	6.0	9.9	15.1	18.7	13.3	2.2	0.07	14.2	24.1	21.7	24.5	19.7	
Temp. Ave. °C.	13.5	25.5	25.0	24.0	14.5	13.0	3.0	1.0	1.0	0.7	1.5	16.5	17.5	20.5	25.0	
pH Average	9.9	9.9	9.3	9.2	8.9	9.4	9.5	7.8	7.5	7.0	7.7	8.9	10.1	10.9	10.5	
Ice Cover (Ponds 1 & 2) (Inches)							3	6	10	15	12					
Odor Detected									x	x	x					

*Number of Stations Sampled to Obtain Average

Table 3A

Chemical Summary - Junction City Sewage Stabilization Pond No. 2

Dates (1957-1958)	5-14	6-18	7-15	8-20	9-24	10-15	11-25	12-17	1-20	2-25	3-11	4-15	5-20	6-16	7-24	Ave.
Composite Pond Sample (ppm)(6)*																
Organic Nitrogen	3.4	6.2	1.6	1.6	1.8	1.4	2.0	2.4	2.8	2.6	3.5	2.6	5.1	1.0	2.0	2.7
Ammonia Nitrogen	.06	.15	.13	.06	.06	.12	.09	1.2	7.0	9.2	9.8	5.3	.06	.06	.24	2.2
Nitrites	<.01	<.01	<.01	<.01	<.01	<.01	<.01	.02	.02	.01	.03	.10	<.01	<.01	<.01	.01
Nitrates	<.3	<.2	<.3	<.1	<.08	<.08	<.08	.12	.12	.08	.08	.56	.08	<.08	<.08	.14
Soluble Phosphorus	.02	<.01	.04	.01	.05	.05	<.01	.08	0.5	1.0	1.08	.19	<.01	.04	.56	0.2
Total Solids	248	244	236	260	266	266	270	302	352	356	320	284	308	224	282	281
Suspended Solids	30	28	10	20	15	5	17	10	18	34	27	30	88	13	10	24
M.P.N. Ave.(x 10^3)(2)*			.8	.05	5.5	22.0	.1	.480	2.8	103.0	64.0	.7	.260	.002	3.4	
B.O.D.(ppm) Ave.(2)*	35.2	16.2	6.6	5.9	8.8	4.5	10.6	7.4	13.9	19.5	16.8	13.7	18.3	7.8	7.5	12.8
D.O. (ppm) Ave. (2)*	11.7	12.3	5.7	10.8	12.0	9.8	24.4	20.7	7.6	2.8	6.0	18.5	15.3	10.3	8.7	
Temp. Ave. °C.	14.5	25.5	26.0	24.0	14.5	13.0	2.0	1.0	1.0	1.0	1.5	15.0	15.5	20.3	25.0	
pH Average	10.2	9.8	8.7	9.2	8.8	9.4	8.9	8.0	7.5	7.0	7.6	8.4	10.3	10.4	9.5	
Odor Detected									x	x	x					

*Number of Stations Sampled to Obtain Average

Table 44

Chemical Summary - New Auburn Sewage Stabilization Pond

Dates (1957-1958)	5-14	6-18	7-16	8-20	9-24	10-15	11-25	12-17	1-21	2-25	3-12	4-24	5-21	6-18	7-23	Ave.
Composite Pond Sample (ppm)(6)*																
Organic Nitrogen	6.4	9.6	6.8	9.8	7.0	5.4	3.2	6.6	4.9	5.4	5.6	8.0	8.5	4.9	9.4	6.8
Ammonia Nitrogen	11.2	6.0	0.7	0.2	2.7	1.4	6.6	12.4	21.0	30.0	31.2	18.4	6.8	1.0	0.3	10.0
Nitrites	<.01	<.01	.05	.04	.13	.04	.02	.01	<.01	<.01	<.01	<.07	.04	.15	<.01	.04
Nitrates	<.3	<.2	<.3	.16	.16	.16	.16	.28	.16	.24	.16	.12	.16	.16	.16	.19
Soluble Phosphorus	4.2	5.3	3.7	3.0	3.4	2.2	3.0	4.6	8.8	11.0	10.0	7.7	7.7	5.6	6.3	5.8
Total Solids	332	378	360	396	360	340	420	400	438	458	438	342	380	308	388	383
Suspended Solids	36	52	54	66	52	39	17	42	34	42	51	57	73	25	66	47
M.P.N. (x 10^3)																
Influent					3,100		110,000	46,000	11,000	22,000	170,000					
Pond Average (3)*			4.6	12.0	11.0	12.0	59.0	1,300	109.0	457.0	263.0	1.15	>2,400		30.0	
% Reduction					99.5		99.9	97.2	99.0	97.9	99.8					
B.O.D. (p.p.m.)																
Influent			284.0	227.0	241.0	246.0	249.0	266.0	321.0	300.0	302.0	261.0	145.0	118.0	202.0	243.0
Pond Average (6)*	23.8	37.7	26.1	32.2	21.9	13.3	11.7	21.5	40.6	82.2	103.9	33.5	36.5	17.9	11.1	35.6
% Reduction			91.0	86.0	91.0	95.0	95.0	92.0	87.0	72.0	65.0	86.0	74.0	84.0	84.0	85.0
D.O. (ppm) Ave. (5)*	1.3	0.2	7.0	8.2	11.1	5.7	2.1	0.4	0.1	0.4	0.0	9.3	15.2	13.1	19.5	
Temp. Ave. °C.	13.0	21.5	24.5	26.0	16.0	11.5	2.0	1.0	0.5	0.5	1.0	11.0	19.5	21.5	24.5	
pH Average	7.5	7.0	7.6	9.0	8.0	8.2	7.6	7.4	7.1	6.9	7.0	7.5	8.7	9.7	9.1	
Ice Cover (Inches)							4	10	15	17	16					
Odor Detected	x	x						x	x	x	x					

*Number of Stations Sampled to Obtain Average

Table 54

Chemical Summary - Spooner Sewage Stabilization Pond

Dates (1957-1958)	5-15	6-19	7-16	8-21	9-25	10-16	11-26	12-18	1-21	2-24	3-24	4-27	5-21	6-18	7-23	Ave.
Composite Pond Sample (ppm)(6)*																
Organic Nitrogen	12.2	7.8	7.6	7.2	8.2	7.6	9.0	10.0	10.3	6.0	6.0	8.8	7.4	8.6	10.0	8.4
Ammonia Nitrogen	18.2	3.8	2.6	2.4	3.7	5.8	6.4	11.6	17.4	18.4	23.0	16.8	9.4	.4	2.4	9.5
Nitrites	<.01	<.01	<.01	.03	.05	.04	.04	<.01	<.01	.02	<.01	<.01	.02	.09	<.01	.02
Nitrates	<.3	<.2	<.3	.16	.16	.2	.24	.24	.16	.12	.12	<.01	.16	.08	.16	.12
Soluble Phosphorus	10.0	8.1	6.1	5.6	7.8	7.8	8.0	9.6	11.4	10.4	11.8	10.8	8.6	1.5	5.9	8.2
Total Solids	427	412	398	410	414	428	484	550	568	460	518	428	450	428	464	455
Suspended Solids	104	58	46	55	59	38	63	67	44	31	30	46	54	66	56	54
M.P.N. (x 10^3)																
Influent			70,000		49,000	13,000,000	92,000	<200.0[1]	7,900	17,000	130,000	54,000	110,000	92,000	33,000	
Effluent			330.0		490.0	460.0	460.0	230.0	1,700	490.0	790.0	170.0	240.0	330.0	240.0	
% Reduction			99.6		99.0	99.9	99.5		78.5	97.1	99.3	99.7	99.8	99.6	99.3	
Pond Averag (3)*			650.0		350.0	950.0	81.0	170.0	690.0	860.0	890.0	140.0	400.0	41.0	3,162	
B.O.D. (p.p.m.)																
Influent	341.0	271.0	236.0	317.0	251.0	346.0	428.0	767.0[1]	328.0	365.0	407.0	400.0	335.0	316.0	122.0	349.0
Effluent	60.5	31.4	28.9	18.6	26.1	18.8	37.6	33.4	69.7	124.0	139.0	50.7	27.1	36.7	20.8	48.2
% Reduction	82.0	88.0	88.0	94.0	90.0	95.0	91.0		79.0	66.0	65.0	87.0	91.0	88.0	82.0	87.0
Pond Average (5)*	60.0	25.0	37.9	19.9	23.2	24.3	25.2	32.9	63.4	111.0	121.0	45.7	37.5	23.8	27.3	33.2
D.O. (ppm) Ave. (5)[1]	0.1	8.4	.2	8.1	3.6	6.3	13.5	1.4	0.5	0.8	0.0	2.5	0.9	27.0	19.2	
Temp. Ave. °C.	11.0	23.0	24.4	24.5	14.0	12.0	1.0	1.0	0.5	1.0	1.0	7.4	16.0	25.0	25.0	
pH Average	8.4	8.5	8.5	8.7	8.3	8.4	8.9	7.9	8.1	7.7	7.9	7.7	8.8	11.1	9.3	
Ice Cover (Inches)							6	12	15	18	18					
Odor Detected	x							x	x	x	x	x				

*Number of Stations Sampled to Obtain Average
1 - pH of Influent 12.9 (Burnt Milk from Creamery)

Table 6A. 24-Hour Survey, Pontoon Sewage Stabilization Pond
August 20, 1958

	Influent p.p.m.	Pond p.p.m.	% Reduction	Influent lbs./Day	Loading[1]
Total N	20.4	4.6	77.4	26.3	8.6
Organic N	2.8	1.2	57.1	3.6	1.2
Inorganic N	17.6	3.4	80.6	22.7	7.4
NH_3 - N	15.0	1.0	93.3	19.3	6.3
Total P	11.6	2.0	82.7	15.0	4.9
Soluble P	11.4	2.0	82.4	14.7	4.8
Total Solids	552.	500.	9.4	711.7	233.4
Susp. Solids	11.	6.	45.4	14.2	4.7
B.O.D.	11.8	1.3	88.9	15.2	5.0

1 - Pounds per 100,000 square feet per day.

Table 7A. 24-Hour Survey, Junction City Sewage Stabilization Ponds
(p.p.m. concentration) - October 15, 1957

	Influent	Pond 1 Effluent	Pond 2 Effluent	% Red. Pond 1	% Red. Pond 2
Total N	30.0	3.8	1.5	87.3	60.5
Organic N	6.0	3.2	1.2	46.6	62.5
Inorganic N	24.0	0.6	0.3	97.5	50.0
NH_3 - N	24.0	0.5	0.2	97.9	60.0
Total P	6.2	1.3	0.2	79.0	84.6
Soluble P	1.9	0.6	0.1	68.4	83.3
Total Solids	458.	314.	256.	31.4	18.4
Susp. Solids	88.	20.	8.	77.2	60.0
B.O.D.	67.6	16.6	4.5	75.4	72.8

Table 8A. 24-Hour Survey, Junction City Sewage Stabilization Ponds[1]
(in pounds of material per day)

	October 15, 1957			August 19, 1958			Loading[2]	
	Influent	Effluent	%Reduction	Influent	Effluent	%Reduction	10-15 1957	8-19 1958
Total N	4.1	0.3	92.6	5.1	0.2	96.0	3.6	4.5
Organic N	0.8	0.2	75.0	1.8	0.2	88.8	0.7	1.6
Inorganic N	3.3	0.1	96.9	3.3	0.02	99.3	2.9	2.9
NH_3 - N	3.3	0.1	96.9	3.3	0.02	99.3	2.9	2.9
Total P	0.9	0.03	96.6	1.1	0.07	93.6	0.8	1.0
Soluble P	0.3	0.01	96.6	0.8	0.06	92.5	0.3	0.7
Total Solids	62.	42.	32.2	81.	27.	66.6	55.	72.
Susp. Solids	12.	1.	91.6	18.	2.	88.8	11.	16.
B.O.D.	9.	0.1	98.8	22.	0.6	97.2	8.	20.

1 - Two ponds in series considered as one unit.
2 - Pounds per 100,000 square feet per day.

Table 9A. 24-Hour Survey, New Auburn Sewage Stabilization Pond

	Influent p.p.m. 8-19-58	Pond p.p.m. 8-19-58	%Reduction	Influent lbs./Day 8-18-58	Influent lbs./Day 8-19-58	Loading[1] 4-8 1958	Loading[1] 8-19 1958
Total N	68.5	14.9	78.2	8.0	9.9	6.8	8.4
Organic N	18.4	14.0	23.9	2.3	2.4	2.0	2.0
Inorganic N	50.1	0.9	98.2	5.7	6.5	4.8	5.5
NH_3 - N	50.0	0.7	98.6	4.8	6.5	4.1	5.5
Total P	18.2	7.6	58.2	1.6	2.4	1.4	2.0
Soluble P	14.8	6.2	58.1	1.0	1.9	0.9	1.6
Total Solids	720.	434.	39.7	111.	94.	94.	80.0
Susp. Solids	118.	116.	1.6	21.	15.	18.	13.
B.O.D.	392.	45.8	88.3	33.	51.	28.	43.

1 - Pounds per 100,000 square feet per day.

Table 10A. 24-Hour Survey, Spooner Sewage Stabilization Pond
(in pounds of material per day)

	December 10, 1957			August 11, 1958			Loading*	
	Influent	Effluent	% Reduction	Influent	Effluent	% Reduction	12-10 1957	8-11 1958
Total N	88.3	28.9	67.2	68.7	27.6	59.8	9.2	7.1
Organic N	47.1	14.3	69.6	29.1	21.6	25.7	4.9	3.0
Inorganic N	41.2	14.6	64.5	39.6	6.0	84.8	4.3	4.1
NH_3 - N	41.2	14.6	64.5	39.2	5.5	85.9	4.3	4.1
Total P				27.6	16.8	39.1		2.9
Soluble P	13.9	15.5		19.3	13.8	28.4	1.4	2.0
Total Solids	1658.	784.	52.7	1131.	1116.	19.9	172.	149.
Susp. Solids	198.	95.	52.0	311.	123.	60.4	21.	32.
B.O.D.	530.	51.	90.3	515.	70.	86.4	55.	54.

*Pounds per 100,000 square feet per day.

Table 11A

Climatological Data

Dates (1957-1958)	5-57	6-57	7-57	8-57	9-57	10-57	11-57	12-57	1-58	2-58	3-58	4-58	5-58	6-58	7-58	57 Annual Ave.
Sunshine																
Madison (% possible)	46	57	56	58	68	62	36	51	53	76	52	57	77	50	60	(-19)[2]
Madison (LTM)[1]	60	67	73	72	70	66	42	41	47	52	59	56	60	67	73	60
Minneapolis (% possible)	53	57	65	67	69	61	27	44	45	71	51	62	73	52	58	(-27)
Minneapolis (LTM)	57	61	69	67	62	59	39	40	50	55	53	57	57	61	69	56
Temperature																
Spooner (average)	53.6	63.6	71.8	66.9	56.1	45.5	30.8	20.3	18.3	11.2	28.6	45.4	55.5	59.1	66.7	42.4
Spooner (depart. LTM)	-1.9	-1.4	1.3	-0.9	-2.4	-2.0	0.4	3.1	5.9	-3.7	2.4	2.7	0	-5.9	-3.8	(-6.2)
Weyerhauser (average)	53.5	62.7	70.3	65.2	54.4	44.4	30.0	19.4	17.7	12.5	29.8	44.0	54.0	57.6	65.2	42.0
Weyerhauser (depart. LTM)	-1.3	-1.1	1.2	-1.3	-3.3	-2.5	-0.4	2.1	4.8	-3.0	3.7	1.5	-.8	-4.2	-3.9	(-10.5)
Stevens Pt. (average)	55.0	66.3	72.1	68.2	58.6	46.7	33.0	23.5	20.8	14.7	31.4	45.2	56.7	62.0	68.3	45.2
Stevens Pt. (depart. LTM)	-2.6	-1.4	-0.7	-2.0	-2.9	-3.0	-0.5	2.8	4.1	-3.5	2.4	.4	-0.9	-5.7	-4.5	(-18.0)
Williams Bay (average)	56.2	67.9	72.7	70.4	61.3	49.7	38.2	30.4	21.2	17.2	33.9	48.0	59.6	62.5	70.0	47.7
Williams Bay (depart. LTM)	-1.5	-.1	-0.6	-1.1	-2.3	-2.9	1.3	5.5	-0.6	-6.2	1.2	1.7	1.9	-9.5	-3.3	(-12.5)
Precipitation																
Spooner (average)	2.39	6.07	5.72	7.00	4.89	1.06	1.75	0.49	.43	.05	.53	2.11	2.75	3.51	6.69	38.09
Spooner (depart. LTM)	-.89	1.68	1.93	3.09	1.73	-.82	.12	-.41	-.38	-.65	-.88	-.12	-.53	-.88	2.90	(5.89)
Holcomb (average)	4.07	6.90	2.78	5.48	2.57	2.01	1.66	0.69	.33	.04	.41	3.39	4.07	5.27	7.93	30.66
Holcomb (depart. LTM)	.31	2.29	-.95	1.80	-1.15	-.04	.09	-.35	-.71	-.82	-1.29	.50	.31	.66	4.20	(4.84)
Stevens Pt. (average)	4.44	2.90	3.66	2.45	2.88	1.01	3.59	.80	.19	.08	.42	2.68	1.65	3.09	2.61	31.99
Stevens Pt. (depart. LTM)	.65	-1.98	.62	-1.24	-.69	-1.16	1.44	-.56	-1.35	-1.28	-1.35	-.08	-2.14	-1.79	-.42	(-11.25)
Williams Bay (average)	5.50	1.81	2.03	4.48	.87	1.21	3.31	2.35	.98	.14		2.02	2.00		2.24	33.11
Williams Bay (depart. LTM)	1.91	-2.27	1.77	.95	-2.49	-.96	.86	.60	-.98	-1.18		-.66	-1.99		-1.56	(-5.60)[3]
Snow on Ground[4]																
Spooner							50	100	100	100	51	7				
Weyerhauser							50	100	100	89	35	3				
Marshfield							53	100	100	82	41	3				
Lake Geneva							7	12	100	85	6					

1 - LTM, long term mean.
2 - Accumulative departure from long term mean in parenthesis for period of study.
3 - No records for March and June, 1958.
4 - Per cent of month ground covered by 1-inch or more of snow.

Table 12A

Biological Summary - Fontana Sewage Stabilization Pond
(Total Count in Number per cc. with Volume (p.p.m.) in Parenthesis)

Dates (1957-1958)	4-18	5-27	6-27	7-29	8-29	9-30	10-24	12-2	12-26	1-30	3-4	4-1	6-25	7-22
BACILLARIOPHYCEAE														
Amphora normani	-	-	-	-	-	-	-	-	-	-	-	-	-	730 (0.1)
Cyclotella spp.	1,130 (0.7)	-	-	-	-	-	-	-	-	-	-	-	-	-
Nitzschia sp.	-	-	-	-	820 (<0.1)	4,990 (0.5)	-	-	-	-	-	2,550 (0.3)	-	-
Surirella sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	20 (0.2)
CHLOROPHYCEAE														
Ankistrodesmus convolutus	-	-	-	-	2,000 (<0.1)	8,721,000 (87.2)	922,180 (11.9)	1,430 (<0.1)	-	-	-	-	-	-
Ankistrodesmus spp.	-	5,300 (1.6)	15,900 (4.7)	1,090 (<0.1)	-	-	-	-	-	-	-	-	40 (<0.1)	-
Chlamydomonas spp.	23,440 (60.2)	2,860 (7.4)	-	-	-	-	-	1,040 (1.8)	1,270 (2.2)	10,860 (19.2)	4,080 (9.2)	32,980 (97.7)	10 (<0.1)	-
Chlorella ellipsoidea	-	-	-	-	-	17,600 (0.4)	4,990 (<0.1)	-	-	-	-	-	-	-
Chlorella vulgaris	-	14,890 (1.0)	8,160 (0.5)	-	-	-	-	-	-	-	-	-	-	-
Chlorogonium euchlorum	109,200 (42.6)	-	-	-	-	-	-	104,660 (26.2)	273,000 (68.3)	27,910 (5.9)	68,290 (9.6)	15,130 (2.1)	-	-
Cosmarium Botrytis	-	-	-	-	-	-	-	-	-	-	-	-	-	480 (12.0)
Scenedesmus spp.	-	164,830 (124.9)	146,970 (117.1)	1,240 (0.3)	2,190 (0.5)	4,590 (0.9)	-	-	-	-	-	-	-	330 (<0.1)
CRYPTOPHYCEAE														
Cryptomonas ovata	-	14,080 (16.2)	300 (0.3)	-	-	-	-	-	-	-	-	-	-	-
EUGLENOPHYCEAE														
Euglena spp.	3,310 (18.6)	-	-	-	-	-	-	-	-	-	-	-	-	-
GRAND TOTAL	137,080 (122.1)	201,960 (153.1)	190,930 (122.6)	2,330 (0.3)	5,010 (0.5)	8,747,780 (89.0)	926,770 (11.9)	107,120 (28.0)	274,270 (70.5)	38,770 (25.1)	72,330 (16.8)	50,240 (60.1)	50 (0.1)	1,560 (12.3)

Table 13A

Biological Summary - Junction City Sewage Stabilization Pond No. 1
(Total Count in Number per cc. with Volume (p.p.m.) in Parenthesis)

Dates (1957-1958)	4-8	9-14	6-18	7-15	8-20	9-24	10-15	11-25	12-17	1-20	3-25	3-11	4-15	5-20	6-16	7-24	8-26
BACILLARIOPHYCEAE																	
Cyclotella operculata	-	-	-	-	-	-	-	2,240 (0.5)	9,190 (1.6)	410 (<0.1)	-	-	3,570 (0.7)	-	-	-	-
CHLOROPHYCEAE																	
Actinastrum Hantzschii	-	-	-	4,070 (1.6)	-	-	-	-	-	-	-	-	-	-	-	-	-
Ankistrodesmus spp.	-	-	-	-	6,500 (0.9)	-	-	-	-	-	-	-	11,480 (1.5)	-	-	-	460 (<0.1)
Chlamydomonas spp.	2 (<0.1)	-	-	-	-	1,210 (0.3)	2,870 (0.8)	19,730 (28.4)	36,760 (52.9)	24,660 (35.5)	16,740 (24.1)	17,200 (17.5)	100 (0.1)	110 (0.2)	-	-	2,050 (3.0)
Chlorella vulgaris	-	-	13,870 (0.5)	-	9,680 (0.3)	-	-	-	-	-	-	-	-	-	-	-	-
Chodatella quadriseta	-	-	-	-	33,660 (4.7)	300 (<0.1)	1,000 (0.1)	2,430 (0.3)	8,190 (1.2)	1,020 (0.1)	1,310 (0.2)	-	45,650 (6.4)	1,861,500 (260.6)	137,360 (19.2)	6,980 (1.1)	640 (0.1)
Coelastrum microporum	-	-	-	4,460 (5.3)	-	-	-	-	-	-	-	-	-	-	-	-	1,820 (3.2)
Dictyosphaerium Ehrenbergianum	-	-	-	930 (0.5)	3,320 (1.7)	-	-	-	-	-	-	-	-	-	-	-	20 (<0.1)
Franceia tuberculata	-	-	10,880 (1.9)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Golenkinia radiata	-	-	29,920 (1.9)	-	-	-	-	2,980 (<0.1)	8,190 (0.1)	3,730 (<0.1)	-	-	651,670 (42.4)	-	-	-	-
Oocystis pusilla	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2,590 (0.9)
Oocystis spp.	-	-	-	410 (0.4)	-	-	-	-	-	-	-	-	-	-	-	-	-
Pandorina morum	-	-	-	-	30 (0.6)	2,990 (56.2)	14,990 (281.1)	-	-	-	-	-	-	-	-	5,720 (107.5)	60 (1.1)
Scenedesmus spp.	-	-	6,430 (1.2)	930 (0.4)	-	1,550 (0.5)	820 (0.3)	-	-	-	-	-	-	29,070 (4.0)	34,680 (10.8)	2,740 (1.3)	-
CRYPTOPHYCEAE																	
Cryptomonas ovata	-	673,200 (269.3)	-	-	50 (0.1)	4,770 (1.3)	-	-	-	2,280 (4.9)	-	-	-	930 (2.0)	1,730 (3.9)	-	20 (<0.1)
CYANOPHYCEAE																	
Oscillatoria sp.	-	-	-	-	-	-	-	-	-	-	-	-	180 (1.6)	140 (1.3)	-	-	-
EUGLENOPHYCEAE																	
Euglena spp.	-	-	-	-	-	-	-	10 (<0.1)	-	-	-	-	-	160 (1.5)	-	-	260 (2.4)
Phacus sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	180 (1.4)
Trachelomonas spp.	1 (<0.1)	30 (<0.1)	10 (<0.1)	410 (0.9)	300 (0.7)	-	-	20 (<0.1)	-	-	-	-	30 (<0.1)	-	-	-	1,230 (3.8)
GRAND TOTAL	3 (<0.1)	673,230 (269.4)	61,110 (5.6)	11,170 (9.1)	53,550 (9.0)	10,820 (67.4)	19,640 (282.3)	27,430 (29.5)	61,330 (55.8)	34,100 (40.7)	18,050 (24.3)	17,200 (17.5)	712,680 (52.8)	1,891,910 (274.6)	173,770 (33.7)	15,460 (109.9)	9,330 (18.0)

Table 14A

Biological Summary - Junction City Sewage Stabilization Pond No. 2
(Total Count in Number per cc. with Volume (p.p.m.) in Parenthesis)

Dates (1957-1958)	4-8	9-14	6-18	7-15	8-20	9-24	10-15	11-25	12-17	1-20	3-25	3-11	4-15	5-20	6-16	7-24
BACILLARIOPHYCEAE																
Cyclotella operculata	-	-	-	-	44,880 (9.0)	65,690 (13.1)	710 (0.1)	202,970 (40.6)	24,270 (4.9)	1,260 (0.3)	-	-	38,760 (7.8)	-	-	-
Nitzschia palea	-	-	205,280 (37.0)	-	180 (9.7)	23,260 (4.2)	1,250 (0.2)	-	-	-	-	-	-	-	-	-
CHLOROPHYCEAE																
Ankistrodesmus spp.	-	-	-	-	-	-	-	-	400 (<0.1)	330 (<0.1)	-	-	-	-	1,700 (0.2)	-
Chlamydomonas spp.	1,130 (0.3)	-	-	-	-	4,080 (1.1)	450 (0.1)	1,130 (1.6)	10,310 (14.9)	11,730 (16.9)	10,860 (15.6)	17,280 (23.7)	20 (<0.1)	-	-	10 (<0.1)
Chlorella vulgaris	-	-	930 (0.1)	2,400 (<0.1)	-	-	-	-	-	-	-	-	-	-	-	-
Chodatella quadriseta	-	-	-	-	-	-	-	-	480 (<0.1)	-	-	-	29,070 (4.1)	469,200 (66.7)	14,110 (2.0)	
Coelastrum microporum	-	-	-	530 (0.5)	80 (0.1)	-	20 (<0.1)	-	-	-	-	-	-	-	-	-
Dictyosphaerium Ehrenbergianum	-	-	-	20 (0.1)	-	-	-	-	-	-	-	-	-	-	-	10 (<0.1)
Franceia tuberculata	-	-	1,130 (0.2)	-	-	-	-	-	-	-	-	-	-	-	-	-
Golenkinia radiata	-	-	510 (<0.1)	-	-	-	-	-	1,600 (<0.1)	250 (<0.1)	-	-	61,300 (4.0)	-	-	-
Oocystis pusilla	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	21,660 (2.4)
Pandorina morum	-	-	-	-	290 (6.0)	130 (2.4)	370 (7.0)	-	-	-	-	-	-	-	-	20 (0.4)
Scenedesmus spp.	-	-	1,580 (0.8)	-	-	4,080 (1.3)	710 (0.2)	-	400 (0.3)	-	-	-	-	204,000 (65.2)	12,980 (4.0	-
CRYPTOPHYCEAE																
Cryptomonas ovata	-	140 (0.1)	3,310 (2.3)	-	-	340 (0.7)	-	-	-	180 (0.4)	-	-	-	360 (0.8)	70 (0.2)	60 (0.1)
Cryptomonas ovata	-	-	-	-	-	-	-	900 (4.8)	-	-	-	-	-	-	-	-
CHAROPHYCEAE																
Unknown unicellular sp.	-	-	-	-	-	-	-	-	-	-	-	-	2,730 (0.3)	-	-	-
EUGLENOPHYCEAE																
Euglena spp.	1 (<0.1)	20 (0.2)	-	-	170 (1.6)	340 (3.1)	130 (1.2)	-	-	-	-	-	140 (1.3)	-	-	10 (0.1)
Trachelomonas spp.	1 (<0.1)	70 (0.2)	-	480 (1.0)	500 (1.1)	90 (0.2)	-	-	-	-	20 (<0.1)	-	230 (0.5)	-	-	20 (<0.1)
GRAND TOTAL	1,134 (0.3)	230 (0.5)	213,720 (40.5)	3,420 (1.6)	99,780 (27.5)	98,030 (26.1)	3,660 (0.8)	204,500 (47.0)	37,460 (20.1)	13,760 (17.6)	10,880 (15.6)	20,020 (24.0)	132,440 (17.9)	673,560 (129.7)	28,800 (6.4)	21,820 (5.0)

Table 15A

Biological Summary - New Auburn Sewage Stabilization Pond
(Total Count in Number per cc. with Volume (p.p.m.) in Parenthesis)

Dates (1957-1958)	5-14	6-18	7-16	8-20	9-24	10-15	11-25	12-17	1-21	2-25	3-12	4-24	5-21	6-18	7-23	8-18
BACILLARIOPHYCEAE																
Cyclotella sp.	-	-	440 (0.3)	30 (<0.1)	80 (<0.1)	60 (<0.1)	-	-	-	120 (0.1)	30 (<0.1)	-	-	-	-	-
CHLOROPHYCEAE																
Ankistrodesmus spp.	20,530 (0.5)	1,430 (1.7)	6,120 (1.9)	-	1,640 (0.1)	22,440 (0.8)	26,950 (0.9)	25,900 (0.9)	4,080 (0.1)	1,270 (<0.1)	-	58,140 (2.0)	-	6,630 (0.2)	-	290 (<0.1)
Chlamydomonas spp.	-	-	7,480 (26.9)	26,260 (94.3)	790 (2.7)	90 (0.3)	50 (0.2)	30 (0.1)	1,390 (0.4)	20,930 (5.7)	45,660 (12.3)	16,290 (41.9)				28,600 (179.0)
Chlorella vulgaris	465,380 (41.9)	-	-	1,270 (0.1)	-	-	2,040 (0.2)	16,070 (1.5)	10,200 (0.9)	1,270 (0.1)	-	26,520 (2.4)	-	-	-	-
Coelastrum microporum	-	2,590 (1.6)	116,900 (68.4)	2,820 (1.5)	2,370 (1.2)	50 (0.1)	4,490 (2.4)	3,570 (1.9)	-	-	-	-	530 (1.4)	45,130 (34.5)	-	-
Crucigenia rotangularis	-	-	-	-	32,130 (3.4)	164,220 (23.8)	-	-	-	-	-	276,420 (25.5)	44,880 (3.8)	8,930 (0.6)	-	-
Eudorina elegans	-	280 (16.2)	-	-	-	-	-	-	-	-	-	-	-	230 (13.3)	-	-
Micractinium pusillum	-	1,470 (8.2)	60 (0.3)	-	-	-	-	-	-	-	-	-	-	-	-	-
Oocystis sp.	1,790 (0.3)	-	2,730 (1.2)	-	-	-	-	-	-	-	-	-	-	-	-	-
Pandorina morum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	12,010 (138.1)	-
Scenedesmus spp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	520 (1.0)	560 (1.1)
Selenastrum minutum	-	-	-	-	-	-	20,400 (1.1)	10,200 (0.6)	2,650 (0.1)	-	-	70,380 (2.5)	697,680 (24.4)	51,510 (1.8)	1,640 (<0.1)	-
CRYPTOPHYCEAE																
Cryptomonas erosa	-	-	-	360 (0.3)	5,170 (3.6)	900 (0.6)	-	-	-	-	-	-	-	-	140 (0.1)	820 (0.6)
EUGLENOPHYCEAE																
Euglena spp.	530 (6.3)	1,600 (18.5)	6,900 (58.4)	-	1,470 (20.8)	1,820 (25.7)	190 (2.7)	520 (7.4)	100 (1.4)	130 (1.8)	30 (0.4)	1,730 (18.5)	1,670 (17.9)	950 (10.2)	840 (9.0)	-
Lepocinclis spp.	-	-	320 (0.5)	-	4,650 (38.0)	50 (0.4)	-	180 (1.5)	40 (0.3)	120 (1.0)	10 (0.1)	460 (3.8)	530 (4.3)	-	-	-
Phacus spp.	890 (3.6)	-	-	-	-	630 (4.7)	300 (2.3)	2,630 (19.7)	840 (6.3)	530 (4.0)	170 (1.3)	370 (2.8)	420 (3.1)	-	-	-
Trachelomonas spp.	90 (0.3)	60 (0.2)	5,620 (3.1)	140 (0.2)	7,830 (49.9)	4,650 (29.6)	280 (1.8)	790 (4.8)	60 (0.4)	90 (0.3)	-	2,750 (8.4)	300 (0.3)	1,250 (3.8)	270 (0.8)	1,010 (3.1)
GRAND TOTAL	489,210 (52.9)	11,430 (44.6)	146,990 (155.0)	30,900 (96.3)	58,090 (119.8)	196,910 (85.0)	54,680 (11.6)	59,450 (38.4)	19,360 (9.9)	24,420 (13.0)	45,890 (14.1)	453,060 (105.8)	746,810 (55.2)	114,630 (64.6)	15,420 (149.0)	61,280 (183.8)

Table 16A

Biological Summary - Spooner Sewage Stabilization Pond
(Total Count in Number per cc. with Volume (p.p.m.) in Parenthesis)

Dates (1957-1958)	5-15	6-19	7-16	8-21	9-25	10-16	11-26	12-18	1-21	2-24	3-14	4-29	5-21	6-18	7-23	8-12
CHLOROPHYCEAE																
Ankistrodesmus spp.	-	290 (<0.1)	-	270 (<0.1)	90 (<0.1)	470 (<0.1)	110 (<0.1)	110	-	-	-	-	-	110 (<0.1)	420 (<0.1)	830 (<0.1)
Chlamydomonas spp.	-	-	-	1,520 (4.7)	160 (1.0)	230 (1.5)	-	-	-	-	-	100 (0.6)	40 (0.3)	-	100 (0.2)	4,200 (9.0)
Chlorella ellipsoidea	187,000 (6.5)	-	-	661,690 (22.8)	1,717,000 (60.1)	1,535,700 (53.7)	1,275,000 (44.6)	777,500 (27.1)	255,000 (8.9)	49,580 (1.7)	27,890 (1.0)	36,720 (1.3)	31,620 (1.1)	-	617,690 (45.5)	770,660 (61.6)
Chlorella vulgaris	85,000 (15.3)	550 (<.01)	1,700 (0.3)	39,670 (7.1)	-	-	-	-	-	-	-	20,400 (3.7)	-	-	10,200 (1.8)	-
Closterium acerosum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	420 (5.9)	1,190 (16.7)
Coelastrum microporum	-	22,140 (139.5)	-	-	-	690 (2.9)	400 (2.2)	140 (0.6)	-	-	-	-	690 (2.0)	31,120 (88.9)	1,250 (2.2)	290 (0.5)
Dictyosphaerium sp.	-	-	-	-	-	-	-	-	-	-	-	-	30 (0.2)	400 (2.9)	790 (5.7)	-
Micractinium pusillum	-	-	-	2,390 (33.8)	-	90 (1.3)	-	-	-	-	-	-	-	-	-	-
Oocystis sp.	-	-	620 (0.4)	1,250 (0.9)	690 (0.5)	300 (0.2)	50 (<.01)	-	-	-	-	-	-	1,180 (1.2)	320 (0.3)	940 (1.0)
Pandorina morum	-	-	2,800 (48.0)	-	-	50 (0.9)	-	-	-	-	-	-	-	1,410 (24.2)	2,820 (48.4)	-
Scenedesmus spp.	1,521,500 (167.4)	230 (0.1)	28,160 (112.6)	150 (<0.1)	160 (<0.1)	1,020 (0.8)	210 (<0.1)	280 (0.1)	-	-	4 (<0.1)	28,560 (3.1)	77,520 (15.9)	1,200 (4.8)	150 (<0.1)	830 (0.4)
Selenastrum minutum	-	-	-	99,170 (4.5)	102,000 (4.6)	1,535,700 (69.1)	3,459,250 (155.5)	1,241,000 (55.8)	1,026,380 (46.2)	383,980 (17.3)	215,960 (4.7)	992,640 (24.9)	589,130 (23.8)	-	-	147,330 (6.6)
Tetraedron mutiam	-	-	-	-	-	56,670 (3.4)	-	-	-	-	-	-	-	-	-	-
CYANOPHYCEAE																
Microcystis aeruginosa	-	-	-	300 (3.6)	-	-	-	-	-	-	-	-	-	-	-	-
EUGLENOPHYCEAE																
Trachelomonas spp.	100 (0.5)	170 (0.4)	430 (1.1)	-	320 (0.8)	50 (0.1)	-	-	-	-	-	30 (<0.1)	-	-	-	-
GRAND TOTAL	1,793,600 (179.5)	23,340 (139.0)	33,720 (162.4)	776,190 (82.4)	1,820,360 (69.0)	3,130,970 (135.9)	4,731,080 (202.3)	2,013,030 (89.6)	1,281,380 (58.1)	433,900 (19.0)	243,830 (10.7)	638,660 (59.6)	698,990 (43.3)	35,420 (122.0)	634,140 (130.0)	924,270 (98.8)

Table 17A
Biological Summary - Complete List of Genera of Algae Isolated in Sewage Stabilization Pond Studies

	Fontana	Jct. City	New Auburn	Spooner
Bacillariophyceae				
1. Amphora	x	-	-	-
2. Cyclotella	x	x	x	x
3. Cymatopleura	-	x	-	-
4. Gomphonema	-	x	-	x
5. Melosira	-	-	x	-
6. Navicula	x	x	x	x
7. Nitzschia	x	x	x	x
8. Surirella	x	-	-	-
Chlorophyceae				
9. Actinastrum	x	x	-	-
10. Ankistrodesmus	x	x	x	x
11. Carteria	-	x	x	x
12. Chlamydomonas	x	x	x	x
13. Chlorella	x	x	x	x
14. Chlorogonium	x	-	-	x
15. Chodatella	x	x	-	-
16. Closterium	-	-	x	x
17. Coelastrum	x	x	x	x
18. Cosmarium	x	x	-	-
19. Crucigenia	-	-	x	-
20. Dictyosphaerium	x	x	-	x
21. Eudorina	-	-	x	-
22. Franceia	-	x	-	-
23. Golenkinia	x	x	x	-
24. Micractinium	-	x	x	x
25. Oocystis	-	x	x	x
26. Pandorina	-	x	x	x
27. Pediastrum	x	-	-	-
28. Polyedriopsis	-	x	-	x
29. Pyrobotrys	-	-	x	-
30. Scenedesmus	x	x	x	x
31. Selenastrum	-	x	x	x
32. Tetraedon	-	x	x	x
Cryptophyceae				
33. Cryptomonas	x	x	x	-
Cyanophyceae				
34. Merismopedia	x	x	x	-
35. Microcystis	-	-	-	x
36. Nodularia	-	x	-	-
37. Oscillatoria	x	x	-	-
Euglenophyceae				
38. Euglena	x	x	x	x
39. Lepocinclis	-	-	x	-
40. Phacus	-	x	x	x
41. Trachelomonas	x	x	x	x
Total	22	30	26	23

Table 18A

Spooner Sewage Stabilization Pond Bottom Fauna Studies

Date	10-16-57	4-29-58	10-14-58
Number of Hman samples	20	20	20
Mean Number of Bottom Organisms per 36 sq. inches	161±35	9±5	239±54
Coefficient of Variation	46	119	48
Estimated Pond Population (x 10^6)	483-751	15-54	709-1,123
Confidence Limits ($\bar{x} \pm t_{05}\, s_{\bar{x}}$)			
$\bar{x}$	161	9	239
t_{05}	2.093	2.093	2.093
$s_{\bar{x}}$	16.5	2.28	25.7
Species Composition (expressed as per cent)			
Chaoborus punctipennis	45.3	33.3	73.6
Tendipes plumosus	44.1	33.3	9.6
Tendipes Tendipediformis	10.6	33.4	15.8

Table 19A

Sediment Accumulation in Sewage Stabilization Ponds

October, 1958

	Fontana			Jet. City I	Jet. City II	Spooner		
	A[1]	B[1]	A & B	Total[2]	Total[2]	A[1]	B[1]	A & B
Number of Samples	14	14	14	14	9	20	20	20
Mean Depth of Deposit (cc.)	2.2±0.7	0.9±0.3	3.0±0.8	2.3±0.7	0.9±0.7	2.7±0.5	1.8±0.3	4.5±0.6
Confidence Limits ($\bar{x} \pm t_{05}\, s_{\bar{x}}$)								
$\bar{x}$	2.16	0.86	3.02	2.28	0.92	2.70	1.83	4.53
t_{05}	2.16	2.16	2.16	2.16	2.31	2.09	2.09	2.09
$s_{\bar{x}}$	0.33	0.13	0.39	0.32	0.29	0.26	0.13	0.30
Range	0.8-4.6	0.0-1.7	1.1-6.0	0.2-4.4	0.0-2.2	1.0-5.0	1.0-3.5	2.5-7.0
Coefficient of Variation	57.9	54.7	47.4	51.8	94.6	43.3	32.8	29.1

1 A. Non-homogenous superficial layer consisting of freshly settled solids.
B. Black homogenous organic layer.

2 "A" layer present in trace amount.

Table 20A

Light Transmission through Snow and Ice - Winter, 1958

Pond	No. Stas.	Date	Mean Snow Thickness Inches	Mean Ice Thickness Inches	Mean Percentage Light Transmitted
Fontana	4	2-22	Trace	18	11.6
Junction City					
Pond I	3	3-10	1.3	12	6.5
Pond II	3	3-10	1.5	15	10.2
New Auburn	4	3-13	2.0	16	3.9
Spooner	3	3-15	3.0	17	4.7

Table 21A

Light Penetration in Sewage Stabilization Ponds and Two Wisconsin Lakes - 1958

Location	No. Stas.	Date	Mean Depth (In.) of Remaining Incident Light 50%	25%	10%	1%	Remarks
Junction City Pond I	3	3-10			1	10	1.3" snow, 12" ice.
		4-15	14	22	33	-	>1% at bottom (45").
		5-20	3	6	10	21	
		6-16	13	25	33	43	
		7-24	12	18	23	30	
		8-9	12	22	37	41	
		8-26	7	18	32	-	>1% at bottom (45").
New Auburn	4	3-13				< 1	2.0" snow, 16" ice.
		4-24	2	5	8	20	
		6-18	6	13	19	25	
		7-23	4	8	14	26	
		8-19	4	8	15	27	
Spooner	4	3-15				7	3.0" snow, 17" ice.
		4-10	4	8	14	27	
		4-29	3	6	11	23	
		5-21	3	6	11	24	
		6-19	6	12	19	33	
		7-23	3	6	11	23	
		8-12	4	9	17	32	
Lake Waubesa (Dane County)	3	6-13	18	47	98	217	Eutrophic lake, 34 feet deep.
Pine Lake (Waukesha Co.)	3	6-12	82	244	406	762	Semi-Oligotrophic lake, 91 feet deep.